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Cargo Logistics Airlift Systems Study (CLASS)

Volume 3. Cross Impact Between the 1990 Market and the Air Physical Distribution Systems

Book 2

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PREFACE

In June 1977, the Douglas Aircraft Company (DAC)was awarded Contract No. NAS1-14948 for the Advanced System Division (ASD) of NASA/Langley Research Center, Langley Field, Virginia, to perform a Cargo/Logistics Airlift System Study (CLASS). The scope of this study as defined by the NASA Work Statement was as follows:

- Characterize current air cargo operations
- Survey shippers to determine nature of demand
- Develop commodity characteristics leading to high elegibility for air transport
- Determine sensitivity of demand to improved efficiency
- Identify research and technology requirements

To comply with the scope of the study, the effort was segregated into five discrete tasks.

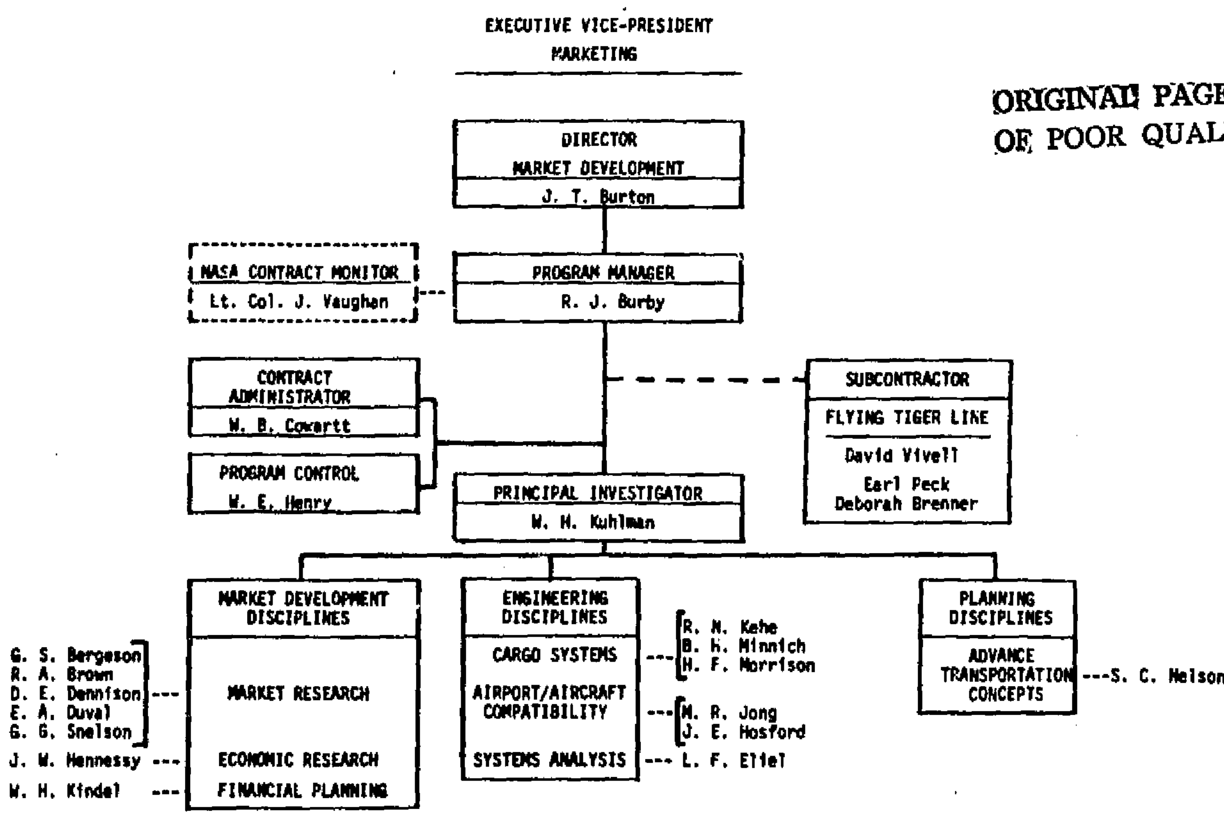
Task 1 was the analysis of the current air cargo system with the objective of clearly understanding what the air cargo operation is today and how prevailing conditions might impact on the 1990 time period. It can be noted here that during the preparation of the Task 1 report deregulation of the air cargo industry was signed into law. The affects of this legislation are not reported and the discussion is maintained as originally written prior to the legislation. This approach was taken in consideration for the short term during which any observation would be presumptuous.

Task 2 was to perform case studies with the objective of determing current distribution characteristics, total distribution cost concepts and their application, and the factors the consignor or consignee considered in their transport mode selection. Concurrent with the case studies was the development of a 1990 scenario designed to provide a framework for the total future environment, within which a 1990 market forecast and the 1990 system characteristics are postulated.

The findings of Tasks 1 and 2 provided the basic information necessary to accomplish Task 3, which was to define the characteristics and require-

ments for the 1990 system. In this task, the market and system growth factors were identified followed by a domestic and international forecast of the 1990 freight market.

The objective of Task 4 was to explain the cross impacts that exist between the air cargo market, technology development and implementation, and the operation of the air physical distribution system. Emphasis was placed upon identifying the factors which had to be considered to measure the possibility of achieving the NASA-defined goals of a 30-percent reduction in aircraft direct operation costs, a 40-percent reduction in indirect operating costs, and a 45-percent reduction in total operating costs. Task 5 identified future system and technology studies and was conducted as an integral effort within all tasks.



The Douglas CLASS study organization is shown above. Douglas is pleased

to acknowledge the excellent contribution made to the project by personnel of the Flying Tiger Line and, in particular, David Vivell, Director of Marketing Research; Earl Peck, Senior Economic Analyst; and Deborah Brenner, Director Advertising. It should be noted that the Flying Tiger team had prime responsibility for Sections 2, 4 and 5 of Volume I; Case Study Approach and Results, Volume II; and Section 6 of Volume III. In addition, they contributed to Section 5 and assisted in the analysis encompassed by Section 2 of Volume I. Douglas appreciates the keen interest and support provided by the NASA contract monitor Lt. Col. John Vaughan.

The study results comprise five volumes:

- Volume I - Analysis of Current Air Cargo Systems, NASA CR158912
- Volume II - Case Study Approach and Results, NASA CR158913
- Volume III - Cross Impact Between the 1990 Market and the Air Physical Distribution Systems
- Volume IV - Future Requirements of Dedicated Freighter Aircraft to Year 2008, NASA CR158950
- Volume V - Summary, NASA CR158951

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ABBREVIATIONS

AADA	Airport and Airway Development Act
ATA	Air Transport Association
ATC	Air Transport Corporation
AWB	Airway Bill (airbill)
CAB	Civil Aviation Board
CAN	Committee on Aircraft Noise
CFR	Code of Federal Regulations
CLC	Consignor-Loaded Container
COFC	Container on Flatcar
COMAT	Airline Company Materials
CRAF	Civil Reserve Air Fleet
DAFRI	Domestic Air Freight Rate Investigation
DOC	Direct Operating Costs
DOD	Department of Defense
DOT	Department of Transportation
DWT	Dead Weight Tons
ETV	Elevating Transfer Vehicles
FAA	Federal Aeronautics Act
FAR	Federal Aeronautics Regulations
FMC	Federal Maritime Commission
GNP	Gross National Product
GRP	Gross Regional Product
HBR	High By-pass Ratio
IATA	International Air Transport Association
ICAO	International Civil Air Organization
ICC	Interstate Commerce Commission
IOC	Indirect Operating Costs
LASH	Lighter Aboard Ship
LCL	Less Than Carload (rail)
LD	Less Developed
LDC	Lower Deck Container Series
LTL	Less Than Truckload
MAC	Mean Aerodynamic Chord
MTOGW	Maximum Takeoff Gross Weight

OAG	Official Airline Guide
O-D	Origin-Destination
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Export Countries
PU&D	Pickup and Delivery
ROA	Return on Assets
ROI	Return on Investment
RRRR(4R)	Railroad Revitalization and Regulatory Reform Act
RTKM	Revenue Tonne-Kilometers
SAF	Society of American Florists
SFAR	Special Federal Aeronautics Regulations
SITC	Standard Industrial Transportation Code
TAA	Transportation Association of America
TDC	Total Distribution Concept
TEU	Twenty-foot-Equivalent Unit
TOC	Total Operating Costs
TOFC	Trailer on Flatcar
TOGW	Takeoff Gross Weight
UD	Underdeveloped
ULD	Unit Load Device
UPS	United Parcel Service
WPL	Weight of Payload

2.4-x 2.4-x 6-meter - metric definition of current 8-x 8-x 20-foot container

SECTION 4

COMMODITIES AND SYSTEM NETWORKS

As we proceed toward the year 1990, trade patterns will change as will the products that are being exchanged. Primary questions of uncertainty deal with the magnitude and types of these potential changes and the associated impact upon the design and operation of the air cargo system can be established. This section takes the initial step in answering these questions by looking at the changing commodity patterns of representative industrial and developing countries and some possible changes in the air networks.

As will be seen in the discussions that follow, the SITC commodity descriptions are not sufficiently detailed to indicate where characteristic changes could affect the details of system design and/or operational procedures. As an example, calculating machines, 71420, encompass the full range of weights, sizes, and shapes now on the market along with all the ramifications of future modifications to these characteristics. In the case of calculators, such modifications will undoubtedly include reductions in size with resulting changes in value and density, thus affecting eligibility and containerization. While analysis of past trade can indicate general future patterns of change, such as the shift from agricultural tools to calculators, the specific changes within a given commodity class require a detailed analysis of the specific supplier and market combination. For these reasons, the CLASS study macro-level analysis, reported on herewith, resulted in the definition of guidelines for possible future trends in commodity classes making up the future air cargo market.

Changing Commodity Patterns In Developed Countries

During the past decade, developed countries of the world have essentially strengthened their relative positions in international trade. While certain third-world countries have made significant gains, over three quarters of total world trade is still generated by developed nations. This trend is

likely to continue past year 2000 for the reason that principal commodities and goods now produced by the majors will prevail because of sheer momentum and established trading markets.

This section is concerned with the analysis of the patterns of trade for the United States with Germany and Japan and of United States exports and imports. Attention was specifically directed to the commodities that moved by air during the years 1973 and 1976. The objective was to discern changes in commodity patterns occurring over this interval of time. Results of this analysis provided a base upon which to project future potential changes in commodities shipped by air.

United States to West Germany air market. - In 1976, 48 175 tonnes of goods moved from the United States to West Germany by air, and of this total air market just 20 commodity groups out of about 900 generated one-half of the air tonnage. Of these prime groups, 17 are rooted heavily in electronics, automotive, and other high-technology products. The remaining three groups are perishables and personal goods. It may be surprising to discover that only 50 percent of these air-transported goods have a stated FOB value greater than $10 per kilogram. The data further reveal that 75 percent of the actual air tonnage is worth more than $5 per kilogram and 90 percent greater than $2 per kilogram. The comparable sea flow in this important trade corridor is mainly comprised of high-bulk, low-value traffic; however, approximately 80 000 tonnes of products with a value greater than $3 per kilogram moved in sea container during 1976. In order to gain some measure of change in product volume over time, trade data were arrayed for 1973 and 1976. Table 4-1 lists selected products moving by air and sea that are of reasonable value and tonnage as discussed in Section 1 of Volume I. The percent change over the 3-year period was calculated for each commodity and shows for air products that thermionic valves, calculating machines, and jet turbines dropped off considerably in air tonnes transported. In the selected sea flows, aircraft parts, photo equipment and tape recorders showed a decline. The changes in volumes transported by either mode could result from competition between the two and a shift one way or the other. It also could be due to natural market forces as between countries A and B or the effect caused by new products in

TABLE 4-1
U.S. TO WEST GERMANY EXPORTS
TOP AIR AND SEA COMMODITIES

SITC	Description	Mode	1973		Average Density (kg/m^3)	1976		Tonne Percent Change
			$/kg	Tonnes		$/kg	Tonnes	
71492	Parts Office Machines	Air	38.61	4 437	205	49.93	4 578	+ 3
72930	Thermionic Valves	Air	33.52	2 686	170	169.22	757	- 72
86169	Photographic Equipment	Air	9.57	1 563	227	16.14	2 521	+ 61
73492	Aircraft Parts	Air	70.71	1 456	170	103.69	1 188	- 19
71420	Calculating Machines	Air	46.11	1 195	275	40.13	66	- 94
72952	Electronic Measuring	Air	47.88	1 113	202	65.01	1 473	+ 32
72220	Electronic Apparatus	Air	27.02	1 040	320	48.42	792	- 24
71980	Mechanical Appliances	Air	23.18	716	376	36.12	796	+ 11
86199	Parts of Measuring	Air	43.11	594	275	55.38	945	+ 59
86171	Medical Instruments	Air	35.45	315	134	50.26	552	+ 75
71142	Jet Turbines	Air	155.13	427	165	258.25	233	- 46
72499	Other Telecommunications	Air	69.13	530	221	93.00	670	+ 26
73492	Aircraft Parts	Sea	40.09	963	170	29.04	603	- 37
21200	Fur Skins	Sea	25.16	311	297	39.68	344	+ 10
86246	Motion Films	Sea	15.55	1 332	611	21.23	2 592	+ 95
71492	Parts Office Machines	Sea	9.12	696	205	10.52	1 025	+ 47
71829	Printing Machines	Sea	8.14	525	693	10.55	432	- 18
86169	Photographic Equipment	Sea	7.85	2 476	227	11.26	1 374	- 45

TABLE 4-1. - Concluded

U.S. TO WEST GERMANY EXPORTS

TOP AIR AND SEA COMMODITIES

SITC	Description	Mode	1973		Average Density (kg/m^3)	1976		Tonne Percent Change
			$/kg	Tonnes		$/kg	Tonnes	
71980	Mechanical Appliances	Sea	5.81	1 135	376	7.75	1 470	+ 30
71510	Machine Tools	Sea	5.37	1 929	472	9.26	1 638	- 15
89111	Tape Recorders	Sea	5.08	1 204	197	6.80	698	- 42
71923	Purifying Equipment	Sea	4.76	1 017	197	7.28	1 004	- 1
89424	Game Equipment	Sea	4.23	2 554	341	5.31	2 719	+ 7
73289	Auto Parts	Sea	2.95	13 400	238	3.80	15 207	+ 13

the categories marketed by country C. The mix of products to Germany will not change appreciably during the next decade because Germany is a developed country and economic balances are well established.

West Germany to U.S. air markets. - In 1976, United States imported 41 548 tonnes of goods from Germany by means of air transport. Roughly 42 percent of these tonnes are represented by the top 20 commodity groups. Of this set 15, or 75 percent, are oriented to electrical, electronic, and mechanical devices. The other five range from personal effects to chemicals and consumer products. The characteristics of Germany's export markets will most likely keep automotive and electrical machines in the forefront for years to come. Table 4-2 is a list of the high-priority air and sea commodities for 1973 and 1976 discussed in Section 1, Volume 1. It would appear by the statistics shown that certain markets, such as knitting machines and parts of office machines, have rapidly declined. Here again, sea mode may be siphoning off business from air or some of those markets may be shifting due to competition. The volume of autos and auto parts moving by sea from Germany to the United States dropped significantly (by 38 percent overall). This was no doubt due to Japanese competition for American markets. In future years, the volume may never return to the high export levels of the early 1970s.

U.S. to Japan air market. - Approximately 37 000 tonnes moved to Japan from the United States in 1976. Roughly 50 percent of this was accounted for by 20 top product groups. About 12 of these commodities are oriented to electronic, mechanical, and other devices. The remainder of the top 20 are divided among food, live cattle, and consumer products. The comparable flow of goods by sea mode indicate over 140 000 tonnes with a value greater than $4 per kilogram. To obtain further perspective of this market, representative products were selected as listed in Table 4-3 (Reference Volume 1, Section 1). We observe from this list of products that sporting goods and medicaments declined substantially in air tonnage. Japan most likely is producing its own products in these product fields which may be the answer to the decline. In the selected sea flows, drastic declines may be noted in the same sporting-goods product line identified in air above and in machine tools and electrical equipment categories. At this date in 1978, it is well known that Japan had

TABLE 4-2

WEST GERMANY TO U.S. IMPORTS

TOP AIR AND SEA COMMODITIES

SITC	Description	Mode	1973		Average Density (kg/m^3)	1976		Tonne Percent Change
			$/kg	Tonnes		$/kg	Tonnes	
71712	Knitting Machines	Air	14.78	2 898	358	12.47	132	- 95
72995	Electrical Condensers	Air	20.09	1 344	350	31.81	283	- 79
71980	Mechanical Appliances	Air	12.69	1 130	376	16.13	1 144	+ 1
71713	Weaving Machines	Air	31.83	1 005	453	31.06	580	- 42
71492	Parts Office Machines	Air	30.24	680	205	48.46	357	- 48
86171	Medical Instruments	Air	37.51	658	134	48.94	706	+ 7
71921	Pumps for Liquids	Air	10.25	560	355	20.13	793	+ 41
71730	Sewing Machines	Air	29.28	500	295	38.36	430	- 14
71954	Machine Tool Parts	Air	14.29	420	184	21.15	434	+ 3
72952	Electrical Measuring	Air	50.79	391	202	49.16	454	+ 16
71410	Cheque Writing Machines	Sea	9.24	5 494	277	11.15	5 630	+ 3
71923	Filtering Equipment	Sea	6.17	2 014	197	7.79	2 490	+ 23
72620	X-Ray Apparatus	Sea	14.95	1 643	151	18.37	2 676	+ 63
71730	Sewing Machines	Sea	10.15	1 566	295	13.83	977	- 38
85102	Leather Footwear	Sea	8.38	1 412	136	9.86	1 660	+ 18
86425	Clock Movements	Sea	7.80	1 332	237	9.83	1 498	+ 12
71962	Filling Machines	Sea	10.13	795	179	14.02	850	+ 7
72504	Electric Shavers	Sea	13.86	579	189	20.86	42	- 93
72960	Electrical Hand Tools	Sea	11.94	437	741	12.90	389	- 11
73210	Autos	Sea	3.03	595 382	128	4.48	361 240	- 39
73280	Motor Vehicle Parts	Sea	2.45	56 800	198	2.96	43 738	- 23

TABLE 4-3

U.S. TO JAPAN - EXPORTS

TOP AIR AND SEA COMMODITIES

SITC	Description	Mode	1973		Average Density (kg/m^3)	1976		Tonne Percent Change
			$/kg	Tonnes		$/kg	Tonnes	
71492	Parts Office Machines	Air	49.87	2 452	205	62.60	2 136	- 13
89442	Archery, Skis, Etc.	Air	11.54	2 173	133	12.48	880	- 60
72220	Electrical Apparatus	Air	24.18	1 316	320	34.30	980	- 25
72952	Electrical Measuring	Air	58.98	1 083	202	79.13	1 045	- 3
86171	Medical Instruments	Air	33.16	371	134	35.02	924	+149
71980	Mechanical Appliances	Air	33.02	829	376	47.64	844	+ 2
73492	Aircraft Parts	Air	69.35	810	170	102.32	708	- 13
72930	Thermionic Valves	Air	197.02	567	170	271.02	409	- 18
86199	Controlling Equipment	Air	56.12	422	275	73.89	456	+ 3
54170	Medicaments	Air	67.10	356	285	64.28	251	- 30
71142	Jet Turbines	Air	166.67	296	165	256.00	281	- 5
72499	Telecommunications Equipment	Air	120.49	265	221	189.04	218	- 18
54170	Medicaments	Sea	22.70	1 090	285	24.86	1 021	- 6
71170	Nuclear Reactors	Sea	18.66	1 213	510	9.79	2 263	+ 86
86246	Motion Picture Film	Sea	13.29	2 723	611	17.46	3 400	+ 25
89442	Archery, Nets Equipment	Sea	10.03	4 250	133	15.80	1 908	- 55
71962	Cleaning Equipment	Sea	9.74	1 050	179	13.15	659	- 38
71510	Machine Tools	Sea	7.23	5 422	472	9.11	2 923	- 46
71921	Pumps	Sea	6.71	1 467	355	8.21	1 715	+ 17
55110	Essential Oils	Sea	6.67	1 353	674	8.59	946	- 30
71923	Purifying Equipment	Sea	6.58	1 140	197	9.23	1 790	+ 57
72210	Electrical Power Machines	Sea	5.96	8 600	342	8.96	1 878	- 79
71980	Mechanical Appliances	Sea	5.53	4 682	376	7.38	2 591	- 45

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over an $8.0 billion positive trade balance with the United States. Japan has made overtures as late as March 1978 toward changing this imbalance. It would appear they will need to increase quotas and reduce import tariffs greatly if they are to alleviate some of this trade gap. A recent Japanese trade mission to the United States had as its objective to contract to buy $1 billion worth of goods before returning to Japan. As of March 13, 1978, the U.S. Commerce Department reported that Japan's industrial leaders had indeed purchased approximately $1.9 billion worth of goods in a commercial swing across the United States. Of this total, industrial and consumer products amounted to $770 million, or roughly 40 percent of total. The remainder of contractual purchases comprised raw materials and feed stuffs. The product portion is of vital interest to air transport and presents new additional volumes and potential to be penetrated. This major effort should begin to loosen the Japanese markets for import of United States goods. In 1976, there was a westbound market imbalance of approximately 43 000 air tonnes. This wide imbalance taken in conjunction with a less-restrictive trade policy presents a much greater opportunity for air growth in the Japan westbound traffic.

Japan to U.S. air market. - Over 80 000 tonnes of goods moved by air from Japan to the United States during 1976, a 64-percent increase over 1973. Of this total, air tonnage of nearly 70 percent was generated by the top 20 commodity groups. Of the top 20, 17 groups represent electronics, automotive, and machinery. The other three are woven fabrics, personal effects, and sporting equipment. The comparable flow of sea goods shows nearly 625 000 tonnes of products flowing from Japan to the United States with a value greater than $4 per kilogram. This does not include 1.5 million tonnes of autos and auto parts also shipped by sea mode in this same market. Table 4-4 lists selected representative commodity flows for both air and sea (Reference Section 1, Volume 1). The only declines in air growth occurred with electrical and telephonic gear, probably due to sustained high production in the United States. All other air categories showed substantial growth, and telecommunication products showed a fantastic 24-fold increase. This market of e electronic devices is, of course, being dominated currently by the Japanese and the level of their export volume proves the point. For sea flow commodities the statistics indicate quite a drop in volume of clothing and

TABLE 4-4

JAPAN TO U.S. IMPORTS

TOP AIR AND SEA COMMODITIES

SITC	Description	Mode	1973 $/kg	1973 Tonnes	Average Density (kg/m^3)	1976 $/kg	1976 Tonnes	Tonne Percent Change
71420	Calculating Machines	Air	15.67	6 092	275	15.20	6 505	+ 7
89111	Gramaphones	Air	10.72	2 941	197	14.62	4 272	+ 45
72995	Electrical Condensers	Air	10.75	2 670	350	22.65	821	- 70
72420	Radios	Air	15.47	1 562	227	16.42	2 947	+ 88
73280	Auto Parts	Air	3.67	1 138	198	4.68	1 010	- 12
72210	Electrical Machines	Air	12.16	1 106	342	9.82	1 463	+ 32
86140	Photographic Equipment	Air	51.88	990	187	69.82	1 614	+ 63
72491	Telephone Equipment	Air	13.15	986	229	14.71	269	- 73
86112	Optical Elements	Air	36.55	878	349	50.81	1 090	+ 24
72492	Microphones	Air	9.90	752	242	9.73	1 041	+ 38
72499	Telecommunications	Air	15.46	701	221	21.48	17 962	+ 2 462
71492	Parts Office Machinery	Air	25.13	604	205	68.41	948	+ 56
86140	Cameras	Sea	38.87	1 863	187	43.72	1 610	- 14
71420	Calculating Machines	Sea	11.84	7 406	275	13.80	9 719	+ 31
72952	Electrical Measuring	Sea	10.67	2 124	202	11.63	2 615	+ 23
86131	Binoculars	Sea	9.82	2 793	451	10.51	2 450	- 12
72491	Telephone Lines	Sea	9.18	5 626	229	4.64	6 062	+ 8
72420	Radios	Sea	8.85	45 215	227	7.58	55 680	+ 23
65351	Fabrics - Woven	Sea	7.69	11 350	234	7.48	14 755	+ 30
72499	Telecommunications	Sea	7.41	19 283	221	8.82	65 014	+ 237
89111	Tape Recorders	Sea	7.16	51 100	197	8.67	69 004	+ 35
84144	Knitted Garments	Sea	6.99	10 536	107	7.38	6 931	- 34
71980	Mechanical Appliances	Sea	6.35	28 585	376	1.68	20 570	- 28
84112	Women's Garments	Sea	5.77	13 140	166	7.84	5 750	- 56

mechanical appliances moving from Japan. The Japanese clothing market is being hotly contested by Taiwan and Hong Kong these days, and the appliance business may have experienced some market shifts. Notwithstanding, Japan provides one of the greatest potential air markets in the world. They export vast quantities of high-value goods, and it is unlikely the profile of products will change by 1990. Air could achieve significant new penetration with sea at competitive prices and service.

Total U.S. exports by air. - To gain additional insight regarding potential of airfreight, the total United States export and import trade data banks were processed for years 1973 and 1976. The top 20 air commodities were identified as the prime group of greater interest. The top three export groups in both 1973 and 1976 were personal goods, auto parts, and office machinery parts. While the actual tonnage for personal goods dropped over this 3-year period, tonnes carried by air for the other two groups increased by more than 12 000 tonnes.

Other major groups in the top 20 included machinery, telecommunications equipment, engines, electrical, and perishables. The total air movement for the top 20 in 1973 was 278 832 tonnes. By 1976, this tonnage grew by 10.6 percent to 295 794 tonnes, accounting for 44.2 percent of total export trade by air. As the inherent characteristics of the top 20 are analyzed, indications are that agricultural markets will experience extensive growth in the 1980s. Present figures record that one-third of United States producing acreage is for export. If this trend continues, air would have an opportunity to participate in these markets for perishables to a much greater degree over the next 10 to 15 years.

A significant product category is excavating and leveling equipment. This group moved from number eight in rank to number five in 1976. The air tonnes nearly doubled over this 3-year span at an average product value of $12.94 per kilogram. Of even greater interest is the half-million tonnes in this group moving by sea mode. At present, the air share is slightly more than 3 percent. While a good deal of these products may be outsize to air transport, a great many construction types of equipment should be open to air penetration. This market will continue to grow rapidly for areas such as the Middle East which is undergoing vast economic changes.

It is interesting to note that 14 of the top air tonnage commodities have a value of more than $10 per kilogram and 11 are worth more than $20 per kilogram. Of the sea trade for the top 20, at least six commodities have a value greater than $10 per kilogram. The average warehouse or packaged density for the top 20 export commodities is 296 kg/m^3. This is in sharp contrast to 200 kg/m^3 for imports. The following four dropped from the top 20 since 1973: calculating machines, taps and valves, fresh vegetables and photographic prints. The following four commodities moved up to the top 20 during 1976: statistical machines, meat and offal, eggs, and medical instruments.

Medical instruments provide an interesting product group for analysis. It moved from position number 28 to number 20 in 1976. The average air value for this product group went from $27.85 to $36.21 per kilogram for a 30-percent increase; the air traffic increased by 62 percent during the same period to over 6200 tonnes. The sea mode transported nearly 9000 tonnes of medical gear worth $9.21 per kilogram in 1976.

On balance, the mix of U.S. exports, i.e., the top 20 commodity groups, are not likely to change substantially over the next 15 years. At present, the U.S. dollar has deteriorated somewhat against major world currencies, but this should have the effect of making U.S. products even more competitive in world markets. United States trade is out of balance due to cost of oil while other products are generally in positive balance. During the next decade, every developing country will surely require increasing volumes of specific kinds of products and goods based on each country's ability to economically assimilate them. The Middle East, for example, is consuming at a high rate both capital and consumer goods and having sufficient dollars with which to pay. It is conceivable later on that the mix of commodities and products will change as those Middle East oil-rich nations become more highly integrated and probably more sophisticated in terms of the 20th century.

<u>California produce 1977 to 1990.</u> - Actual data for the years 1968-1976 were obtained from the USDA, "Air Shipments of California Fruits and Vegetables," Federal State Market News Service. Data were available for both domestic and export air shipments. The actual data are characterized by extremely wide percentage changes year by year. For example, domestically,

the percentage change has ranged from a plus 46 percent to a minus 14. Export shipments show even greater fluctuations ranging from a plus 136 percent to a minus 71 percent.

During the time period studied, export shipments increased more than domestic shipments. In 1968, domestic air shipments were 25 241 metric tonnes increasing 32 percent to 33 105 in 1976; whereas, export air shipments in 1968 were 2049 metric tonnes increasing 355 percent to 9315 in 1976. The distribution of this produce is discussed in Section 1 of Volume 1.

Between 1971 and 1972, the largest decreases occurred domestically (-14 percent) and the second largest (-37 percent) for export. Reasons for this decrease were attributed to (1) fewer maritime strikes; (2) to a lesser extent, more Pacific ports improved their facilities to handle containerized boat shipments; (3) more favorable surface freight rates; (4) there were 500 fewer acres of strawberries planted in California for harvest; and (5) the California grape production was much less because of frost damage.

During the 9-year period, the largest decrease (-71 percent) exported occurred in 1975. This is attributed to one of the major airlines being unable to furnish adequate capacity for produce shipments and to the lessening of demand due to withdrawal of armed services personnel from the Pacific Area.

From this analysis, it is possible to determine major factors affecting air shipments of fresh fruits and vegetables. They are (1) labor (strikes), (2) technical (containerization and the ability of seaports to handle containers), (3) agriculture plantings, (4) climatic conditions, (5) favorable rates, (6) aircraft availability, and (7) major conflicts or peace.

Single factor regression analysis was utilized to forecast air shipment of California fresh fruits and vegetables from 1976 to 1990. The single factor was historical growth rates from 1968 to 1976. Attempts to utilize other factors affecting air transport of produce were considered but not utilized because of their near total incapability of being forecast for even a short period of time much less 14 years.

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It is possible that the application of single-factor regression analysis provides a conservative forecast. Regardless, a significant tonnage of produce is forecast to be moving by air in 1990 as shown in Figure 4-1. Domestically, air shipments will increase 53 percent from 35 868 tonnes in 1976 to 54 866 tonnes in 1990. Exports will increase 89 percent from 7026 to 13 298 tonnes.

Total U.S. imports by air. - The 1973 and 1976 total United States trade was processed and arrayed in highest to lowest air tonnes by commodity group. Between 1973 and 1976, personal goods and leather footwear retained positions one and two and knitted garments moved from number ten to position number three. The air tonnage generated by the top three grew from 100 000 air tonnes in 1973 to nearly 110 000 by 1976. The following commodities moved into the top 20 during this period: men's clothing, live plants, archery and sports equipment, crustacea, articles of plastic, and electrical apparatus. The following commodities dropped out of the top 20: electrical condensors, internal combustion engines, fresh vegetables, vacuum flasks, knitted fabrics, and bananas.

The total air tonnage generated in 1973 by the top 20 was 216 399 compared to 280 584 in 1976. This represented a 30-percent growth over the 3-year span. In examining the mix of import commodities it is obvious that clothing and apparel dominate. No doubt Americans wear considerable clothing fabricated in places such as Hong Kong, Taiwan, Italy, etc. It is interesting to note that we export high tonnages of fabrics, mainly by sea mode, presenting an added opportunity for air transport of finished goods back to the States. This situation allows United States companies to take advantage of the cheaper labor pools to be found abroad. Of course, the United States imports a large volume of automobiles and electronic equipment. Japan and Germany are heavy producers in these markets. The total motor vehicle parts market, for example, is near the 570 000-tonne level. Air has only slightly more than 1 percent of this traffic. Over the next few years it is entirely possible for the air mode to make substantial inroads to this market. The value per kilogram is not high, but the density and transportability of motor vehicle parts point to much higher air potential. As one looks further at the top 20 air tonnage commodities, it becomes obvious that in addition to the clothing and apparel segment, electronic machines, radios, etc., comprise the other main sector of products carried by air. The value of electronics

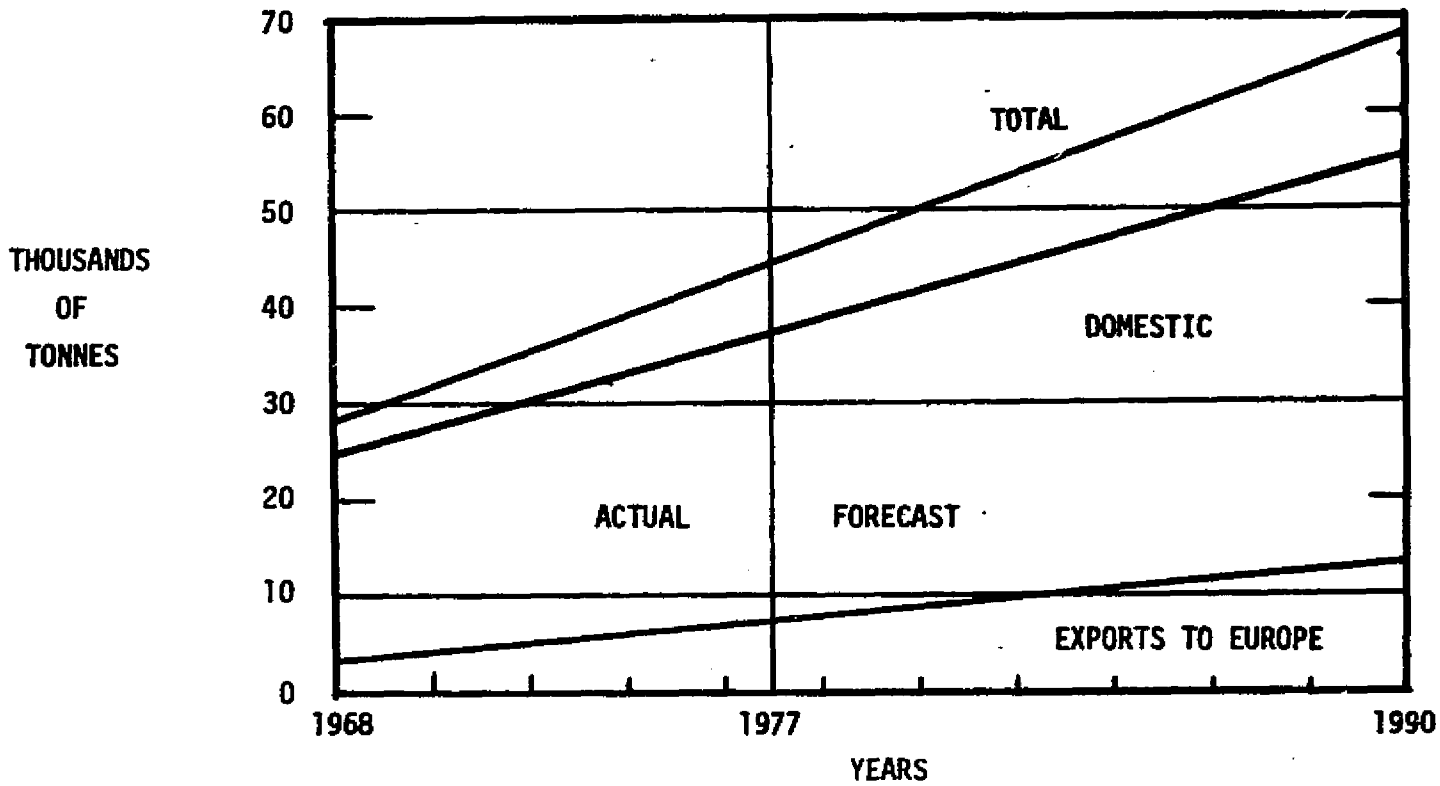

Figure 4-1. Air Shipments of California Fresh Fruits and Vegetables, Domestic and European Countries, 1968-1990

is generally high and provides a spectrum of products for which the economics of air transport apply. The profile of most air markets will change in the years ahead due to new technology (such as microminiaturization in electronics). However, basic products will still have to be packaged for shipping, and densities will remain near what they are today due to inherent product characteristics. The element that will change in the future is location of markets and attendant flow volumes. These will rise and fall with factors of self-sufficiency, protectionism, trade agreements, and the vital need to trade.

Changing Patterns of Imports by Developing Country

The objective of this analysis is to investigate the past imports of developing countries and to thereby identify changes in commodity types that will provide a basis for projecting future commodity patterns of emerging countries. The statistical data source for this analysis is a printout of United Nations commodity data reference. To reduce the quantity of this data to manageable proportions, it was necessary to establish certain criteria of commodity acceptability. These criteria are: the commodity must have a minimum dollar value per kilogram of $10 and in one of the two years considered (1972 or 1975) must have a minimum of 10 000 kilograms imported by the considered country. The years 1972 and 1975 were selected because 1972 is the first year this information was added to the MDC data bank and 1975 is the most current year available.

Trading partners for the emerging countries were selected on the basis of their trade during 1972 and 1975 and their level of industrialization. Although the United States is a major trading partner with many of the emerging countries considered, it is not included in the analysis due to the incompatibility of the applicable United Nations data currently on hand. The following emerging countries are considered in the discussion that follows: New Zealand, Republic of Korea, Pakistan, Singapore, Brazil, and Morocco. A brief economic description of the level of manufacturing, foreign trade, and an analysis of the commodities imported, will be provided for each of these selected countries.

New Zealand. - The New Zealand economy is characterized by a high degree of dependence on agriculture, especially livestock farming, and the export of agricultural products, notably temperate foodstuffs. Strenuous efforts have been made since the mid-1940s to promote manufacturing and thereby diversify the economy in order to insulate it to some degree from fluctuations in traditional export markets. These efforts have not been too successful in reducing New Zealand's dependence upon wool, meat, and dairy products.

In the decade from the mid-1960s, labor productivity in the economy as a whole rose by an average of 1.5 percent per year, with agriculture and the services group showing virtually no growth, whereas manufacturing achieved an average annual increase of 3 percent. The greatest achievement was in the public utilities sector. Manufacturing in the earlier postwar years also registered relatively high productivity growth (from a low base in most cases). The overall performance of the New Zealand economy in recent years has been unimpressive with a record of slow growth in real terms, rapid inflation, and recurring balance of payments difficulties.

On a more positive note, the Australian-Japanese consortium, which operates a large aluminum smelter based on power from a state-owned hydroelectric station and using Queensland alumina, has met or exceeded production estimates. The great bulk of the resulting metal is exported to assured markets in Australia and Japan. Aluminum fabrication and semifabrication have also expanded substantially in recent years.

Imports to New Zealand that meet the previously stated criteria are shown, unordered, in Table 4-5. Although total imports from Japan and the United Kingdom show a decrease of 3.9 percent, this decrease occurred because of a 16.9 percent decrease of imports from the United Kingdom. Imports from Japan increased 99.4 percent. This observation is significant in that it demonstrates a lessening of the long-standing trade affiliation between New Zealand and the United Kingdom which accounted for 60 percent of New Zealand's total imports in 1950 and had diminished to 19 percent in 1975.

Importation of certain commodity groups, for example, 10 electronic/

TABLE 4-5

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO NEW ZEALAND FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		United Kingdom		Total	
	1975	1972	1975	1972	1975	1972	1975
Interchangeable Tools, Hand Machine Tools	12.43	9	12	70	116	79	128
Typewriters and Check Writing Machines	11.22	19	13	68	92	87	105
Calculating Machines, Accounting Machines	33.16	46	43	54	69	100	112
Statistical Machines, e.g., Calculators	55.59	17	32	35	78	52	110
Pumps for Liquids	10.00	33	34	493	243	526	277
Motorized Hand Tools, Nonelectric	14.17	31	12	49	82	80	94
Machines for Cleaning, Filling Bottles	17.16	28	25	247	118	275	143
Apparatus For Making, Breaking or Projecting Electrical Circuits	12.85	124	105	625	641	749	746
TV Broadcast Receivers	10.00	4	218	3	55	7	273
Radio Broadcast Receivers	14.24	155	92	6	13	161	105
Electrical Line Telephone and Telegraph	10.00	47	901	425	516	472	1417
Other Telecommunication Equipment	22.95	23	124	131	178	154	302
X-Ray Apparatus	13.18	5	17	24	22	29	39
Electric Lamps	22.63	11	16	128	243	139	259
Other Electrical Measuring and Controlling Instr.	24.94	22	34	49	42	71	76
Electro-Mechanical Hand Tools	11.84	64	85	130	252	194	337
Electrical Condensers	20.92	35	21	33	95	68	116

TABLE 4-5. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO NEW ZEALAND FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		United Kingdom		Total	
	1975	1972	1975	1972	1975	1972	1975
Knitted Crocheted Fabrics, Elastic	10.50	6	12	16	8	22	18
Optical Elements Mounted	88.26	2	10	57	-	59	10
Photographic Cameras	37.76	23	39	-	-	23	39
Cinematographic Cameras, Projectors	25.27	18	18	-	-	18	18
Photographic Equipment, N.E.S.	14.53	8	36	125	193	133	229
Drawing, Measuring, Calculating Equipment	15.58	61	19	67	104	128	123
Photographic Plates, Film	10.80	25	28	15	32	40	60
Film in Rolls, Sensitized, Unexposed	19.40	3	24	24	9	27	33
Clocks, N.E.S.	22.00	14	67	6	35	20	102
Gramaphones, Tape Recorders, Etc.	13.27	92	98	91	55	183	153
Parts, Tape Recorders, Etc.	22.60	17	10	11	21	28	31
Phonograph Records and Recorded Tapes	11.18	9	24	34	68	43	92
Balalaikas, Banjos, Guitars, Lutes	10.00	47	30	-	-	47	30
Electrical Musical Instruments	10.36	26	42	-	-	26	42
Advertising Catalogues, Charts	17.13	23	16	221	148	244	164
Fishing, Hunting Equipment	11.59	101	32	4	12	105	44
Cattle Live	16.42	-	-	442	122	442	122
Horses and Mules Live	38.11	-	-	745	28	745	28

TABLE 4-5. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO NEW ZEALAND FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		United Kingdom		Total	
	1975	1972	1975	1972	1975	1972	1975
Radio Active and Associated Material	12.82	-	-	-	16	-	16
Medicaments	1S.07	-	-	947	775	947	775
Other Pharmaceutical Good	16.36	-	-	13	22	13	22
Mixtures of Odoriferous Substance	10.00	-	-	61	74	61	74
Hygienic Pharmaceutical Articles	10.00	-	-	24	17	24	17
Yarn of Wool or Animal Hair	10.18	-	-	24	17	24	17
Cotton Yarn and Thread, Bleached	13.57	-	-	125	74	125	74
Cotton Yarn and Thread, Retail	15.13	-	-	25	76	25	76
Flax Ramie Yarn	11.82	-	-	14	17	14	17
Yarn of Continuous Synthetic Fibre	10.00	-	-	231	212	231	212
Fabrics,Woven Wool, Fine Animal Hair	14.21	-	-	333	141	333	141
Fabrics, Woven, Discontinuous Synthetic	10.00	-	-	78	65	78	65
Knitted or Crocheted Fabrics	10.00	-	-	215	128	215	128
Narrow Fabrics, Other Than Woven	10.00	-	-	20	12	20	12
Other Tulle Net Fabrics, Lace	16.15	-	-	32	34	32	34
Other Textile Fabrics	10.00	-	-	59	62	59	62
Shapes, Sections Wire Nickel	11.56	-	-	22	16	22	16
Knives	10.12	-	-	20	30	20	30

TABLE 4-5. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO NEW ZEALAND FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		United Kingdom		Total	
	1975	1972	1975	1972	1975	1972	1975
Scissors and Their Blades	10.06	-	-	10	16	10	16
Spoons, Forks, Tableware	13.72	-	-	14	18	14	18
Steam Engines	13.69	-	-	768	29	768	29
Internal Combustion Engines	50.32	-	-	9	34	9	34
Water Turbines, Other Engines	10.83	-	-	17	29	17	29
Other Engines, N.E.S.	20.83	-	-	29	12	29	12
Other Agriculture Machinery	17.92	-	-	-	12	-	12
Parts of Office Machinery	29.59	-	-	43	133	43	133
Typemaking, Setting Machinery	15.87	-	-	71	87	71	87
Air Conditioning Machines	11.50	-	-	58	14	58	14
Furnace Burners, Mech. Stokers	10.13	-	-	82	49	82	49
Calenering Machines	13.56	-	-	298	27	298	27
Automatic Vending Machines	10.31	-	-	6	13	6	13
Machinery Parts, Non-Electric	12.09	-	-	166	43	166	43
Electric Shavers and Hair Clippers	18.75	-	-	9	16	9	16
Thermionic, Etc. Valves and Tubes	13.57	-	-	97	115	97	115
Electric Traffic Control Equipment	12.41	-	-	9	17	9	17
Electrical Parts, N.E.S.	18.29	-	-	108	91	108	91

TABLE 5. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO NEW ZEALAND FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		United Kingdom		Total	
	1975	1972	1975	1972	1975	1972	1975
Electrical Equipment, N.E.S.	45.30	-	-	30	10	30	10
Parts For Motorcycles	10.05	-	-	-	10	-	10
Aircraft Parts	71.94	-	-	34	38	34	38
Floating Structures, Not Vessels	12.09	-	-	-	234	-	234
Chairs, Seats, Parts	11.64	-	-	32	11	32	11
Outer Garments, Knitted Crocheted	13.76	-	-	22	21	22	21
Footwear of Leather	10.02	-	-	166	233	166	233
Medical Instruments and Appliances	28.43	-	-	35	44	35	44
Mechanical Therapy Appliances	17.75	-	-	10	12	10	12
Technical Demonstration Models	14.00	-	-	23	45	23	45
Industrial Mechanical Testing Devices	12.92	-	-	14	12	14	12
Liquid Flow Depth and Pressure Devices	10.92	-	-	68	119	68	119
Instruments For Physical/Chemical Analysis	17.31	-	-	7	16	7	16
Parts of Measuring or Controlling Instruments	24.07	-	-	23	28	23	28
Unissued Postage Stamps, Bank Notes	12.48	-	-	-	58	-	58
Antiques, N.E.S.	43.48	-	-	3	23	3	23
Organo Sulphur Compounds	27.64	-	-	14	13	14	13
Bacterial Products, Vaccines	13.88	-	-	25	8	25	8

TABLE 4-5. - Concluded

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO NEW ZEALAND FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		United Kingdom		Total	
	1975	1972	1975	1972	1975	1972	1975
Essential Oils and Resinoids	12.90	-	-	12	7	12	7
Razors and Razor Blades	14.02	-	-	22	7	22	7
Weaving, Knitting Machines	10.50	-	-	106	387	106	387
Under Garments, Knitted	10.36	-	-	11	9	11	9
Mechanical Lighters	14.63	-	-	10	7	10	7
TOTALS....................................		1148	2289	9132	7585	10280	9874
Percent Change Total 1972-1975		99.4%		(16.9%)		(3.9%)	

electromechanical commodities which are used primarily by industry increased 80 percent. Another example is the increase in the number of business machine commodities imported. The total of three commodities in this group increased 37 percent. Still another indication of the trend toward an industrial rather than agricultural economy can be noted in the decrease of two classifications of livestock from 1 187 000 to 150 000 kilograms. A new commodity appears in this tabulation, namely radioactive and associated material which, once again, indicates a move toward advanced technology. An increase from 106 000 to 387 000 kilograms of weaving and knitting machines indicates the manufacture of goods from New Zealand wool rather than export of the raw material.

Republic of Korea. - When the Republic of Korea launched its first 5-year Economic Development Plan in 1962, high priority was given to development of manufacturing industry. The share of the sector in GNP increased from 13.5 percent in 1961 to 22.8 percent in 1971. In subsequent years, its performance was equally impressive. The sector grew by 30.9 percent in 1973 and, despite the slowdown in the economy, still achieved a 16.1 percent growth rate in 1974. The most buoyant branches of industry during this period were textiles (including leather), fabricated metals (including machinery and electronics), iron, steel, and paper.

The expanding industrialization of the Republic of Korea is apparent from the type and increase of commodities being imported as presented, unordered, in Table 4-6. Fourteen commodity classifications of communication and electronic equipment imports increased from 6 266 000 to 10 592 000 kilograms, 69 percent. From 1972 to 1975, the combination of the classifications, steam engines and internal combustion engines, increased 94 percent. Machinery for textile bleaching, washing, and printing increased from 62 000 to 496 000 kilograms, indicating the continual growth of the textile industry.

The increase in consumer purchasing power is indicated by the 44 percent increase in four classifications of photographic equipment. An increase from 2000 to 144 000 kilograms of other food-processing machines is indicative of diversification into new industries.

TABLE 4-6

VOLUME CHANGE OF HIGH VALUE IMPORTS TO KOREA FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Enzymes	10.80	27	35	-	24	27	59
Vitamins And Provitamins	13.77	35	50	-	-	35	50
Penicillin, Streptomycin, Tyrocid	46.84	19	55	5	10	24	65
Opium Alkaloids, Cocaine, Caffeine	10.00	7	43	-	-	7	43
Medicaments	17.93	189	42	70	53	259	95
Mixtures Of Odoriferous Substance	12.76	207	308	2	32	209	340
Perfumery, Cosmetics, Dentrifices	19.46	9	13	-	-	9	13
Leather, Goat Kid Skins	17.24	17	42	-	-	17	42
Other Leather	12.11	59	342	-	-	59	342
Manufactures Of Leather, N.E.S.	17.89	9	19	-	-	9	19
Silk Yarn	85.27	9	30	-	-	9	30
Silk Fabrics Woven	63.03	65	118	-	-	65	18
Fabrics, Woven Wool Fine Animal Hair	10.29	406	1038	-	-	406	1038
Woven Labels Badges, Etc.	29.64	22	14	-	-	22	14
Embroidery	18.34	8	32	-	-	8	32
Other Textile Fabric Articles	24.50	59	52	-	-	59	52
Other Made-Up Textile Articles	11.03	28	29	-	-	28	29
Synthetic Precious Stones, Not Set	48.30	1	15	-	-	1	15

TABLE 4-6. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO KOREA FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Silver Unwrought, Partly Worked	83.57	2	14	-	-	2	14
Platinum, Etc. Unwrought, Partly Worked	130.26	-	13	-	-	-	13
Tube And Pipefittings Of Copper	11.03	49	33	-	-	49	33
Shapes Sections Wire Nickel	21.96	5	28	-	-	5	28
Aluminum Foil	10.34	110	248	-	-	110	248
Tinfoil, Powders And Flakes	14.31	5	42	-	-	5	42
Nuts, Bolts, Screws Copper	13.58	1	24	-	-	1	24
Interchangeable Tools, Hand Machinery	12.43	86	609	-	-	86	609
Of Iron Or Steel	11.30	51	44	-	-	51	44
Articles Of Copper, N.E.S.	15.76	36	34	-	-	36	34
Other Dairy Machinery	12.81	28	21	1	57	29	78
Calculating Machines, Accounting	33.16	59	84	-	-	59	84
Statistical Machines, Calculators	61.82	11	39	-	-	11	39
Parts Of Office Machinery, N.E.S.	36.74	21	141	-	-	21	141
Machines, Auxiliary Weaving, Knitting	11.17	942	630	52	72	994	702
Glass Working Machinery	12.54	70	133	-	-	70	133
Motorized Hand Tools And Electric	11.47	60	157	-	-	60	157
Metal Plastic Joints	19.42	8	12	-	-	8	12

TABLE 4-6. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO KOREA FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Apparatus For Making And Breaking Or Projecting Electrical Circuits	12.00	2068	4172	23	738	2091	4910
TV Broadcast Receivers	10.00	725	403	-	-	725	403
Radio Broadcast Receivers	14.24	1250	1447	-	-	1250	1447
Electrical Line Telephone And Telegraph	37.37	205	164	672	919	877	1083
Other Telecommunications Equipment	22.95	310	994	-	-	310	994
Electro-Medical Apparatus	21.85	6	20	-	-	6	20
X-Ray Apparatus	24.20	79	65	13	17	92	82
Electric Accumulators	12.26	29	57	-	-	29	57
Electric Lamps	18.55	95	64	-	-	95	64
Thermionic, Etc. Valves And Lamps	80.58	236	673	-	-	236	673
Other Electrical Measuring And Controlling Instruments And Apparatus	37.76	309	314	4	23	313	337
Electro-Mechanical Hand Tools	11.84	21	27	-	-	21	27
Electrical Condensers	20.92	161	364	-	-	161	364
Electrical Equipment, N.E.S.	19.03	60	131	-	-	60	131
Men's, Boy's Outer Garments	10.68	7	74	-	-	7	74
Clothing Accessories, N.E.S.	10.14	94	103	-	-	94	103
Compound Opitcal Microscopes	32.14	8	14	-	-	8	14

TABLE 4-6. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO KOREA FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Optical Appliances And Instruments	24.94	3	16	-	-	3	16
Photographic Cameras	37.46	28	122	-	-	28	122
Cinematographic Cameras, Projectors	25.27	20	12	-	-	20	12
Image Projectors	41.20	27	10	-	-	27	10
Photographic Equipment, N.E.S.	14.83	19	95	-	-	19	85
Medical Instruments And Appliances	11.87	30	94	-	-	30	84
Medical Therapy Appliances	25.08	4	13	-	-	4	13
Gas Liquid Supply Meters	15.91	9	11	-	-	9	11
Survey Instruments, Etc.	31.63	14	19	-	-	14	19
Drawing Measuring, Calculating Instruments	22.79	67	108	-	-	67	108
Technical Demonstration Models	16.40	5	15	-	-	5	15
Liquid Flow, Depth, And Pressure Instruments	18.56	106	133	9	15	115	148
Instruments For Physical/Chemical Analysis	30.06	20	18	-	-	20	18
Parts of Measuring/Controlling Instruments	16.75	121	310	-	-	121	310
Photographic Plates/Film	10.80	34	128	-	-	34	128
Film in Rolls, Sensitized, Unexposed	19.40	32	74	-	-	32	74
Clock Movements Assembled	14.20	46	44	-	-	46	44
Gramophones, Tape Recorders, Etc.	13.27	912	936	-	-	912	936

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TABLE 4-6. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO KOREA FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Phonograph Records And Recording Tapes	11.18	19	231	-	-	19	231
Parts Of Firearms	19.48	-	46	-	-	-	46
Fishing Hunting Equipment	11.59	50	90	-	-	50	90
Jewelry, Precious Metals	19.80	-	12	-	-	-	12
Articles Of Wax, Natural Gums	22.56	246	10	-	-	246	10
Mechanical Lighters	22.08	4	13	-	-	4	13
Oxygen Function Compounds	14.17	-	-	-	90	-	90
Knitted Or Crocheted Fabrics	13.00	-	-	-	10	-	10
Nuts, Bolts, Screws, Iron And Steel	10.69	-	-	7	13	7	13
Steam Engines	12.04	-	-	10	125	10	125
Internal Combustion Engines	17.87	-	-	513	1066	513	1066
Machine Tools For Working Metals	14.81	-	-	189	769	189	769
Textile Bleaching, Washing, Printing Machines	10.61	-	-	62	496	62	496
Book Binding Machinery	11.57	-	-	25	14	25	14
Other Food Processing Machines	11.30	-	-	2	144	2	144
Pumps For Liquids	14.50	-	-	59	38	59	38
Machine Tools For Working Wood And Plastics	11.80	-	-	3	10	3	10
Machine Tool Parts	19.87	-	-	9	30	9	30

TABLE 4-6. - Concluded

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO KOREA FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Machines For Cleaning/Filling Bottles	12.89	-	-	50	101	50	101
Ball, Roller/Needle Roller Bearings	10.41	-	-	12	22	12	22
Machinery And Mechanical Appliances	22.96	-	-	696	272	696	272
Transmission Shafts, Cranks, Pulleys	11.69	-	-	20	170	20	170
Electric Furnaces, Electric Welding Equipment	11.05	-	-	6	128	6	128
Electric Traffic Control Equipment	52.40	-	-	19	99	19	99
Special Purpose Lorries Trucks	22.82	-	-	61	17	61	17
Clock And Watch Parts, N.E.S.	10.00	-	-	1600	123	1600	123
TOTALS..................................		10199	16219	4194	5697	14393	21916
Percent Change Total 1972-1975.............		59.0%		35.8%		52.3%	

Pakistan. - Industry in Pakistan is still unsophisticated. Textiles, for example, are concentrated at the relatively cheaper end of the scale, largely turning out grey cloth. Textiles, which form the bulk of manufactured exports and are the mainstay of manufacturing industry, were badly affected by the 1975 recession and are still faring badly, hampered by restrictions imposed by the developed countries. For all that, economists have been impressed by the enterprise of Pakistanis. That enterprise shows clearly in small-scale industries which have been much more successful than their larger counterparts, so much so that organizations such as the World Bank recommend that more encouragement should be given to smaller-scale industries. This sector has recorded some notable success stories; for example, the sports goods industries and the carpet makers who have contributed greatly to Pakistan's export drive.

Three commodities contribute significantly to the increase in import volume from 1972 to 1975. These three commodities, TV broadcast receivers, hygienic pharmaceutical articles, and gas turbines, were not imported in any significant quantity from the two trade partners considered in 1972, but accounted for 1 602 000 kilograms in 1975 as shown, unordered, in Table 4-7.

Despite the previously stated fact that Pakistan's manufacturing industry was badly affected by the 1975 recession, imports from the two trading partners increased 53 percent from 1972 to 1975. Although there were decreases in certain commodities used in manufacturing, it could be explained by cautious spending during a recession year rather than a lessening of the trend toward industrialization.

Singapore. - Manufacturing activity, stimulated by government industrial promotion efforts, expanded rapidly between 1968 and 1974 at 16 percent annually. However, in 1974 it grew by only 3.9 percent and in 1975 declined by 1.6 percent. With the upturn in the economy in 1976, the manufacturing sector recovered to achieve a growth rate of 10 percent. The current strategy for the future development of the manufacturing sector is to shift the emphasis to establishing high-technology industries with a more skill-intensive labor mix. Industries which have shown rapid growth include petroleum products, shipbuilding and repairing, basic metals, and metal products.

TABLE 4-7

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO PAKISTAN FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
TV Broadcast Receivers	10.00	-	412	-	-	-	412
Pumps for Liquids	10.00	49	191	40	-	89	191
Other Telecommunications Equipment	22.95	35	97	-	-	35	97
Hygienic Pharmaceutical Articles	13.19	-	89	-	-	-	89
Apparatus for Making and Breaking Electrical Circuits	17.65	194	84	401	228	595	312
Phonograph Records and Recorded Tapes	11.18	1	42	-	-	1	42
Photographic Plates, Films	10.80	11	38	-	-	11	38
Other Electrical Measuring Equipment	21.23	8	31	7	14	15	45
Photographic Equipment, N.E.S.	11.84	-	31	6	10	6	41
Interchangeable Tools, Hand Machinery	12.43	6	26	11	-	17	26
Motorized Hand Tools, Nonelectric	10.87	1	23	-	-	1	23
Electrical Condensors	20.92	34	23	19	14	53	37
Electrical Line Telephone and Telegraph	27.45	46	20	148	144	194	164
Cyclic Alcohols Dorivatives	20.11	5	19	-	-	5	19
Electrical Equipment, N.E.S.	17.42	1	19	60	11	61	30
X-Ray Apparatus	12.50	4	16	16	21	20	37
Other Printing Machinery, N.E.S.	10.20	9	15	78	-	87	15

TABLE 4-7. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO PAKISTAN FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Film in Rolls Sensitized	19.40	11	30	-	-	11	30
Calculating Machines, Accounting	33.16	6	11	-	-	6	11
Fountain Pens, Penholders, etc.	10.00	5	11	-	-	5	11
Vitamins and Provitamins	15.12	4	11	-	-	4	11
Gas Turbines, Other Than For Aircraft	10.29	-	-	1	1101	1	1101
Machinery and Mechanical Appliances	11.30	-	0	315	329	315	329
Machines Auxiliary Weaving, Knitting	11.00	-	-	167	202	167	202
Machines Tools for Working Metals	10.40	-	-	233	129	233	129
Internal Combustion Engines	13.82	-	-	367	93	367	93
Medicaments	13.72	-	-	96	87	96	87
Heterocyclic Compounds	14.36	-	-	43	80	43	80
Hygienic Pharmaceutical Articles	13.55	-	-	-	55	-	55
Typewriters and Check Writing Machines	13.09	-	-	17	45	17	45
Machine Tool Parts	10.69	-	-	43	42	43	42
Corsets, Suspenders, Garters	13.93	-	-	10	27	10	27
Steam Engines	44.82	-	-	8	17	8	17
Water Turbines, Other Engines	17.41	-	-	-	17	-	17
Furniture Parts, N.E.S.	10.23	-	-	23	13	23	13

TABLE 4-7. - Concluded

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO PAKISTAN FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Medical Instruments and Appliances	20.08	-	-	17	13	17	13
Drawing Measuring, Calculating Equipment	24.50	-	-	5	12	5	12
Articles of Unhardened Rubber	13.82	-	-	21	11	21	11
Other Textile Fabrics Articles	15.80	-	-	11	10	11	10
TOTAL..................................		430	1239	2163	2725	2593	3964
Percent Change Totals, 1972-1975.........		188.1%		25.9%		52.9%	

Table 4-8 illustrates the industrialization growth of Singapore by the 47 percent increase in high-value imports from Japan. This increase is especially noticeable in the 68 percent increase for the total of 11 classifications of communications and electronic equipment. The affluence of the Singapore industry can also be observed in the 86 percent increase in four classifications of photographic and cinematographic equipment. Additional evidence of the increasing purchasing power of the population can be noted in the 32 percent increase in tape recorders, phonograph records, and musical instruments.

Brazil. - Since the early 1960s, increased emphasis has been laid on industrial development, and manufacturing accounted for over 20 percent of Brazil's gross domestic product in 1974. The government's industrial policy includes self-sufficiency programs in agrochemicals, fertilizers, paper, cellulose, nonferrous metals, steel, pharmaceuticals, and petrochemicals. However, agricultural production still provides a large proportion of Brazil's export earnings, the principal export cargo being coffee, sugar, and soybeans. The present steel expansion program plans to increase annual output to 20 million metric tons by 1978 and a 3.4 million ton steel plant is to be built with Japanese participation.

Brazil possesses vast mineral reserves, the leading export being iron ore with the deposits at Serra dos Carajás in Amazonia estimated to be the largest in the world: 18 000 million tons of over 60 percent iron content. Other minerals include the 350 million tons of phosphate discovered in Minas Gerais and deposits of uranium, manganese, and copper located within the country.

The unordered tabulation of high-value imports to Brazil, Table 4-9, is quite indicative of the country's stage of development. For example, 18 percent increase for five categories of telecommunications equipment indicates the modest but continued need to expand communication networks between the mining sites and other far-flung raw material deposits and the headquarters offices that direct operations. Another example of this tapping of vast mineral deposits is the increased requirement for calculating and business machines, 80 percent, and parts of office machinery, 125 percent. Other

TABLE 4-8

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO SINGAPORE FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan	
	1975	1972	1975
Crustacea and Mollusks, Fresh	10.24	27	34
Vegetables, Dehydrated	11.26	301	622
Mixtures of Odoriferous Substance	10.50	16	12
Monofil, Etc. of Synthetic Fibers	16.61	26	283
Other Tulle Net Fabrics, Lace	13.95	7	22
Embroidery	13.02	15	56
Other Textile Fabrics	10.38	5	16
Tungsten Wolfram	14.18	-	17
Finished Structural Parts	10.63	10	19
Interchangeable Tools, Hand Machinery	12.43	53	114
Cutting Blades for Machines	10.30	65	44
Gas Turbines	12.70	270	82
Agricultural Machines	10.79	15	24
Typewriters and Checque Writing Machines	11.22	35	58
Calculating Machines, Accounting	33.16	111	244
Statistical Machines, Calculators	93.56	6	18
Parts of Office Machinery, N.E.S.	26.00	4	122
Gas Operated Welding, Cutting	13.12	48	25

TABLE 4-8 Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO SINGAPORE FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan	
	1975	1972	1975
Machines Auxiliary Weaving, Knitting	17.27	71	15
Motorized Hand Tools	11.23	39	62
Machines for Cleaning Filling Bottles	11.17	25	30
Metal Plastic Joints	10.68	18	28
Apparatus for Making and Breaking Elec. Circuits	12.70	1034	998
Other Insulating Fittings	10.38	51	16
TV Broadcast Receivers	10.00	629	902
Radio Broadcast Receivers	14.24	1994	2197
Electrical Line Telephone and Telegraph	11.52	63	1374
Other Telecommunications Equipment	22.95	92	302
Electric Lamps	10.72	145	101
Thermionic, Etc. Valves and Tubes	27.79	143	597
Other Electrical Measuring Equipment	26.01	77	92
Electro-Mechanical Hand Tools	11.84	51	40
Electric Sound Visual Signalling	13.37	15	41
Electrical Condensers	20.92	257	194
Electrical Equipment, N.E.S.	27.38	23	29
Women's Girdles, Infants Outer Garments	13.69	22	35

TABLE 4-8. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO SINGAPORE FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan	
	1975	1972	1975
Hand Kerchiefs	12.60	19	20
Schawls, Scarves, Mufflers, Etc.	13.89	8	18
Corsets, Suspenders, Garters	11.82	21	22
Stockings, Etc. Knitted Crocheted	14.20	21	15
Under Garments, Knitted Crocheted	11.29	49	41
Outer Garments, Knitted Crocheted	14.07	66	44
Headgear, Non-Felt	13.50	7	10
Optical Elements, Mounted	88.26	13	37
Frames For Spectacles, Etc.	71.30	8	10
Spectacles	29.38	107	52
Binoculars and Refracting Telescopes	16.23	31	44
Optical Appliances and Instruments	11.76	10	25
Photographic Cameras	37.76	148	231
Cinematographic Cameras, Projectors	25.27	65	88
Image Projectors	10.06	35	16
Photographic Equipment, N.E.S.	12.62	24	171
Counting Devices	20.40	-	10
Survey Instruments	24.00	20	30

TABLE 4-8. - Continued

VOLUME CHANGE OF HIGH - VALUE IMPORTS TO SINGAPORE FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan	
	1975	1972	1975
Hydrometers, Thermometers, Etc.	15.41	9	22
Liquid Flow, Depth, and Pressure Instruments	20.71	92	14
Parts of Measuring or Controlling Instruments	23.90	34	39
Photographic Plates, Film	10.80	40	50
Films in Rolls	19.40	39	26
Watch Cases, Parts Thereof	33.76	4	31
Clock, Movements Assembled	14.20	355	161
Clock and Watch Parts, N.E.S.	10.02	9	346
Gramaphones, Tape Recorders	13.27	1128	1264
Parts Tape Recorders	10.16	97	416
Phonograph Records and Recorded Tapes	11.18	168	161
Balalaikas, Banjos, Guitars	13.12	11	17
Fishing Hunting Equipment	11.59	54	42
Fountain Pens, Pen Holders	10.14	165	234
Imitation Jewelry	16.59	35	37
Mechanical Lighters	22.08	64	91
Clocks, N.E.S.	22.00	37	129

TABLE 4-8. - Concluded

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO SINGAPORE FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975
(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan	
	1975	1972	1975
Compound Optical Microscopes	22.33	15	6
Pearls, Not Set or Strung	20.00	10	3
TOTAL......................................		8 781	12 937
Percent Change Total, 1972-1975...........			47.3%

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TABLE 4-9

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO BRAZIL FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Apparatus for Making and Breaking	15.74	2206	1063	1157	1250	3363	2313
Electrical Line Telephone and Telegraph	21.31	715	830	217	1097	932	1927
TV Broadcast Receivers	10.00	43	2110	-	-	43	2110
Radio Broadcast Receivers	11.24	358	696	-	-	358	696
Calculating Machines, Accounting	33.16	229	443	30	23	259	466
Gramaphones, Tape Recorders, Etc.	13.27	1118	419	25	44	1143	463
Other Telecommunications Equipment	22.95	115	360	134	71	249	431
Photographic Plates,Film	10.80	105	277	116	148	221	425
X-Ray Apparatus	12.87	85	229	153	172	238	401
Statistical Machines	55.53	129	217	228	33	357	250
Medical Instruments and Appliances	13.71	128	189	30	48	158	237
Phonograph Records and Recorded Tapes	11.18	87	144	128	34	215	178
Photographic Cameras (other than cinematographic)	37.76	109	140	26	49	135	189
Photographic Equipment, N.E.S.	10.69	43	124	10	8	53	132
Mechanical Lighters	22.08	72	117	-	-	72	117
Drawing,Measuring and Calculating Instruments	18.81	133	110	116	160	249	270
Film in Rolls sensitized unexposed	19.46	69	103	158	142	227	245
Other Electrical Measuring and Controlling Instr.	36.60	115	103	129	168	244	271

TABLE 4-9. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO BRAZIL FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Motorized Hand Tools non-Electric	10.46	30	101	215	394	245	445
Interchangeable Tools, Hand	12.43	31	100	269	141	300	241
Electro-Mechanical Hand Tools	11.84	36	68	133	136	169	204
Pocket Watches, Wrist Watches	190.68	31	65	-	-	31	65
Parts of Office Machinery, N.E.S.	76.22	12	64	67	114	79	178
Parts, Tape Recorders, Etc.	12.62	75	61	34	69	109	130
Cinematographic Cameras	25.27	41	60	4	10	45	70
Agriculture Machines, Harvesting	14.34	15	58	1017	2310	1032	2368
Liquid Flow, Depth, and Pressure Measuring Instr.	18.00	29	56	43	62	72	118
Hydrometers, Thermometers	20.24	43	50	10	8	53	58
Gas Operated Welding, Cutting, Etc. Machines	10.10	1300	49	41	48	1341	97
Electrical Condensors	20.92	68	45	7	18	75	63
Hunting, Fishing Equipment	11.59	116	45	-	-	116	45
Compound Optical Microscopics	36.26	31	34	10	13	41	47
Duplicating Addressing, Etc. Machines	16.29	110	31	46	37	156	68
Electrical Traffic Control Equipment	52.10	11	29	-	-	11	29
Electrical Equipment, N.E.S.	48.25	23	28	773	396	796	424
Shapes Sections Wire Nickel	20.21	18	24	37	46	55	70

TABLE 4-9. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO BRAZIL FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Electric Lamps	33.00	54	24	47	42	101	66
Furnace Burners, Mechanical Stokers	23.22	8	23	26	64	34	87
Slide Fastners, Parts Thereof	13.43	2	23	-	-	2	23
Seeds, Fruit and Spores For Planting	25.41	32	22	-	-	32	22
Survey Instruments, Etc.	26.00	24	22	29	17	53	39
Musical Instruments	10.80	66	20	-	-	66	20
Machines For Cleaning, Filling Bottles	19.37	23	19	1356	432	379	451
Electro-Medical Apparatus	72.53	8	17	9	13	17	30
Electric Accumulators	10.82	25	17	20	20	46	37
Industrial Mechanical Testing Devices	12.55	39	17	146	48	185	65
Enzymes	10.25	7	16	-	-	7	16
Electrical Sound Visual Signalling Apparatus	49.69	20	16	-	-	20	16
Parts of Measuring or Controlling Instruments	53.13	10	16	46	49	56	65
Typewriter and Cheque Writing Machines	11.22	40	14	179	98	219	112
Counting Devices	18.93	-	14	3	11	3	25
Other Articles of Cutlery	10.31	17	13	20	23	37	36
Binoculars and Telescopes	12.00	7	13	-	-	7	13
Medicaments	18.93	34	12	155	332	189	344

TABLE 4-9. - Concluded

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO BRAZIL FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	Japan		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Of Iron or Steel	10.27	5	11	20	77	25	88
Advertising Catalogues, Charts	23.90	34	10	19	48	53	58
Broom, Brushes, Mop, Paint, Rollers	13.30	7	10	-	-	7	10
Optical Elements Mounted	88.26	5	10	-	-	5	10
Narrow Fabrics Other Than Woven Labels, Badges, Etc.	18.14	17	7	-	-	17	7
Shawls, Scarves, Mufflers, Veils, Etc. Not Knitted	15.00	39	6	-	-	39	6
TOTALS....................................		8402	9014	6493	8514	14895	17528
Percent Change Total, 1972-1975............		7.3%		31.1%		17.7%	

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examples, such as an increase in agricultural and harvesting machines of 130 percent in the 3 year period, indicate retention of the basic agricultural production. It is also noticeable that few high-volume luxury consumer goods appear on the list, indicating a comparatively low amount of disposable income per capita.

Morocco. - Morocco has a congenial climate, varied soils with good agricultural potential. There is an emerging industrial sector, a small but growing managerial class, and the beginnings of an industrial force. The economic infrastructure (transport, communications, electric energy) is at an advanced stage. The problems that Morocco has to face are familiar among developing countries. The fast-rising population, increasing by 3 percent per annum, is supported for the most part by an out-of-date agricultural system, and any substantial increase in the country's productive capacity is dependent on foreign finance. Several foreign companies contribute to the country's manufacturing capacity. These include a tire plant by Goodyear, a plant to produce plastics, medicines, and other chemical goods by the West German concern, Hoechst. The emphasis in industry is on labor-intensive light industry which will produce import substitutes and goods for export. Industry is perhaps the least stagnant of the economy and promises the highest rate of growth in the immediate future.

Although the majority of the population has very little purchasing power, there is nevertheless a fairly large market for many consumer goods among the two or three million people who are better off. Encouraged by government promotion, many new enterprises have been established to produce goods that formerly had to be imported. Food processing, which is export oriented, has emerged during the past few years. Next to the food industries in importance are the textile and leather industries. A metal products industry is also well established. In the chemical sector, the most significant plants are in the crude oil refinery and the Safi phosphate complex, which is being expanded to produce 7 500 tons of phosphoric acid a day. There are plans to build two sulphuric acid units at Safi and a $1300 million steel complex at Nador.

In Table 4-10 we can observe this accelerated industrialization in such examples as a 105 percent increase in 3 years of five classifications of

TABLE 4-10

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO MOROCCO FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	France		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Apparatus for Making and Breaking Electrical Circuits	10.01	917	1227	33	89	950	1316
Medicaments	12.43	982	1184	132	57	1114	1241
Electrical Line Telephone and Telegraph	25.08	180	847	11	25	191	872
Other Telecommunications Equipment	29.48	74	291	16	38	90	329
Gas Turbines	11.66	-	229	-	-	-	229
Interchangeable Tools, Hand Machinery	10.02	49	225	-	-	49	225
Furniture Parts, N.E.S.	11.33	35	196	-	-	35	196
Textile Bleaching, Washing, Machinery	11.50	-	134	-	-	-	134
Fabrics Woven	10.14	54	133	-	-	54	133
Mixtures of Odoriferous Substances	10.07	81	122	-	-	81	122
Machines for Washing, Filling Bottles	13.28	41	109	50	132	91	241
Parts of Measuring or Controlling Machinery	17.36	97	97	-	-	97	97
Motorized Hand Tools, Non-Electric	13.57	-	96	-	-	-	96
Electricity Supply Meters	12.81	76	90	-	-	76	90
Electric Starting Ignition Equipment	12.63	64	73	17	21	81	94
Bacterial Products, Vaccine	20.00	45	62	-	-	45	62
Electrical Lighting Vehicles	11.64	83	59	-	-	83	59

TABLE 4-10. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO MOROCCO FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	France		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Statistical Machines, Calculators	48.78	28	58	-	-	28	58
Technical Demonstration Models	15.95	16	58	-	-	16	58
Other Printing Machinery, N.E.S.	10.60	28	57	-	-	28	57
Pile Chenile Fabrics, Regenerated	22.29	34	51	-	-	34	51
Other Electrical Measuring Instruments	40.31	44	48	-	-	44	48
Other Textile Fabrics and Articles	14.91	34	47	-	-	34	47
Advertising Catalogs, Charts	10.00	39	47	-	-	39	47
Gold Silversmiths Wares	12.29	9	47	-	-	9	47
Steam Engines	18.90	3	41	2	28	5	69
Fountain Pens, Penholders	11.51	11	41	-	-	11	41
Razors and Razor Blades	13.35	117	40	-	-	117	40
Jewelry, Precious Metal	19.80	10	38	-	-	10	38
Medical, Scientific, Optical Instruments	11.13	8	37	-	-	8	37
Heterocyclic Compounds	34.17	29	36	-	-	29	36
Metal Plastic Joints	13.76	35	34	-	-	35	34
Phonograph Records and Recorded Tapes	22.45	57	30	-	-	57	30
Machinery	10.59	54	29	-	-	54	29
X-Ray Apparatus	27.00	20	29	-	-	20	29

TABLE 4-10. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO MOROCCO FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	France		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Women's, Girl's, Infant's Garments	23.28	28	29	-	-	28	29
Machine Tool Parts	22.18	-	28	-	-	-	28
Fabrics Woven	10.04	49	26	-	-	49	26
Medical Instruments and Appliances	20.92	16	26	-	-	16	26
Photographic Equipment, N.E.S.	13.12	15	25	11	20	26	45
Aircraft Parts	140.52	7	23	-	-	7	23
Cotton Yarn and Bleach	10.09	90	22	-	-	90	22
Chairs, Seats, Parts	10.73	18	22	-	-	18	22
Men's, Boy's Outer Garments	15.27	11	22	-	-	11	22
Film in Rolls Sensitized	30.95	19	22	12	12	31	34
Organo-Therapeutic Glands, Compounds	13.35	21	20	-	-	21	20
Cotton Yarn and Threads	13.90	16	20	-	-	16	20
TV Broadcast Receivers	12.68	344	19	10	28	354	47
Microphones, Loud Speakers	21.17	8	18	7	13	15	31
Liquid Flow Depth and Pressure	33.89	30	18	-	-	30	18
Vitamins and Provitamins	14.33	12	17	-	-	12	17
Electric Traffic Control Equipment	15.88	21	16	-	-	21	16
Footwear of Leather	14.50	19	16	-	-	19	16

TABLE 4-10. - Continued

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO MOROCCO FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	France		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Parachutes	22.69	7	16	-	-	7	16
Duplicating Addressing Machines	13.36	12	14	-	-	12	14
Cutting Blades for Machines	12.08	12	12	-	-	12	12
Optical Appliances and Instruments	11.75	4	12	-	-	4	12
Survey Instruments	39.33	8	12	-	-	8	12
Domestic Utensils, Copper	14.27	7	11	-	-	7	11
Electrical Equipment, N.E.S.	15.27	8	11	-	-	8	11
Typewriter, Similar Ribbons	17.36	5	11	-	-	5	11
Other Pharmaceutical Goods	15.74	10	11	-	-	10	11
Machine Leather Belting	16.80	10	10	-	-	10	10
Outer Garments, Knitting	19.80	6	10	-	-	6	10
Other Cinema Film Developed	39.90	7	10	-	-	7	10
Interchangeable Tools Machinery	9.71	49	48	-	-	49	48
Clock and Watch Parts, N.E.S.	12.50	18	-	-	-	18	-
Cotton Yarn and Thread	10.81	16	20	-	-	16	20
Internal Combustion Engines	10.50	-	-	145	185	145	185
Machines Auxiliary Weaving Knitting	16.70	-	-	46	61	46	61
Sewing Machines	17.27	-	-	12	45	12	45
Typewriters and Check Writing Machines	11.95	-	-	10	38	10	38

TABLE 4-10. - Concluded

VOLUME CHANGE OF HIGH-VALUE IMPORTS TO MOROCCO FROM SELECTED INDUSTRIALIZED COUNTRIES, 1972-1975

(Thousands of Kilograms)

Commodity Description	Value $/kg	France		Germany		Total	
	1975	1972	1975	1972	1975	1972	1975
Bookbinding Machinery	10.33	-	-	1	36	1	36
Radio Broadcast Receivers	29.65	-	-	7	17	7	17
Thermionic, Valves and Tubes	11.47	-	-	24	15	24	15
Spraying Machinery	13.33	-	-	9	12	9	12
Electric Furnaces	13.70	-	-	5	10	5	10
TOTALS......................................		4257	6539	560	882	4817	7421
Percent Change Totals, 1972-1975............		53.6%		57.5%		54.1%	

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electrical communications equipment and the entry in volume of gas turbines at 229 000 kilograms in 1975 compared to none from these trading partners in 1972. A similar situation occurs with the importation of 134 000 kilograms of textile bleaching machinery in 1975 to none in 1972. In fact, few examples can be found in the entire tabulation which do not show a modest or large increase in all classifications of commodities required for an increase in industrial production. This outstanding economic performance occurred not in a period of expansion but in a time of worldwide recession.

Future commodity patterns. - Developing countries have separate and distinct characteristics with respect to the socioeconomic, geographical, cultural, or political elements of its total environment. In addition, the stage of development of each of these elements differs with each country. The one characteristic which they have in common is the requirement to determine and execute a plan for transporting goods which is especially adapted to the present and sufficiently flexible to augment industrial growth in future years. The transportation system developed will, to a great extent, influence the future growth pattern of the country and, consequently, the commodity pattern of the future. For example, many of the developing countries have vast untapped natural resources, mineral and agricultural, which constitute their primary export commodity. Unless an efficient and economical transportation system is developed it will not be possible to transport these natural resources to internal factory locations for processing/manufacturing purposes or to seaports for export. Assuming an adequate transportation system is planned and put into effect, the flow of raw materials will provide the capital necessary for continued economic growth including an increase in gross domestic product and disposable income.

A limited food supply has been a principal deterrent to development in many countries despite the fact that many of these countries have a vast and, in many cases, unmeasured amount of arable land. For example, as of 1960 only 11 percent of potentially arable land in South America was cultivated in contrast to 51 percent in North America and 88 percent in Europe.

Some of the elements of the infrastructure necessary to utilize arable land are technical assistance, transportation networks, storage facilities,

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processing plants, a system for dissemination of commodity market information, and the availability of credit for traders. Assuming these necessary elements are provided, a developing country can manage to produce sufficient foodstuffs for their population and hopefully have a surplus for export. Development of mineral resources would require almost identical infrastructure elements. From these requirements, it is obvious that the initial import requirements for a developing country are commodities such as earth-moving equipment, farm machinery, mining equipment, power plants, fertilizers, and fuels.

After development of mining and agricultural resources, the next logical economic development would be the processing of raw materials into a form immediately usable by the trading partner, e.g., iron ore to steel bar stock. Proceeding to this stage of industrial development requires imports of power equipment, manufacturing machinery, electrical and electronic controlling equipment, office machinery, transportation equipment, and the chemicals necessary for some manufacturing processes. During, or possibly previous, to this development stage, health needs of the population would receive the necessary attention by authorities. Establishment of health care centers requires the importation of medicines and pharmaceutical products, hospital supplies, diagnostic and therapeutic instrumentation and equipment. In addition, as this stage of development progresses, the need for communication equipment, electrical line, and telegraph equipment increases and must be imported.

During the preceding stages, it is assumed that the economic planners of the emerging country have foreseen the requirement for semiskilled labor, craftsmen, skilled workers, technicians, and managers. Such a manpower pool is required for the next stage of development which entails the fabrication of industrial and consumer commodities from available natural resources. This phase, in turn, will require a different classification of imports, namely, specific types of manufacturing equipment for various industries, measuring and controlling devices, packaging machinery, factory handling equipment, etc.

As the progressive development stages evolve, skills of the labor force

increase and salaries become more than adequate to sustain a reasonable standard of living leading to an increase in disposable income. In this economic atmosphere, there is a consumer demand for commodities unavailable in the native land. Such a demand will be met by industrialized countries with consumer goods of all varieties ranging from cosmetics to refrigerators. At this point in time, the developing country has reached an economic stage where, with appropriate leadership, continued progress is nearly inevitable with an increasing demand for more sophisticated commodities.

The current state of development combined with future progress will determine the evolving commodity patterns of any considered developing country. To determine what this pattern will be over a given future time period requires the detailed analysis of that country's environment and developing patterns viewed in the context of the current world situation.

To assure adequate service, such studies should be performed by the airlines whose network encompasses the country of interest. An attempt was made to define general trends in commodity change that would provide a guide for these types of studies. However, as evidenced by the preceding discussion, the available data on developing countries do not cover a sufficient time span to establish a relationship between commodity change and national development.

Potential Network Changes

Of prime concern in the development of the future air cargo system is the question of service and its effect upon the market. In preparation for the subsequent analysis of service elasticity and operating cost, the following discussion will address several possible changes in the air networks that are likely to occur in the future. While there are three basic approaches to affecting service, frequency, origins and destinations, and routing of aircraft, the following remarks are limited to the latter two approaches and their effect on freight volume, stage length, and modifications to network configurations.

Future stage lengths. - As we proceed into the future, there will be changes in trade patterns from the standpoints of routes and volume flow. Domestically, there will be changes due to the 1978 deregulation of the air

cargo industry. While such wide-sweeping changes in policy are not anticipated for international operations, changes in world trade and possible variations in airline operational techniques have the potential to perturb the present volume-range relation.

The variation of cargo flow with stage length for the domestic air network is shown in Figure 4-2. From 1969 on, there has been a steady increase in mean stage length until 1976 when there was a slight decline undoubtedly due to the recession. If the future continues as the past, we would expect additional increases in the mean range once steady economic recovery is underway. However, speculations are that this increase in mean range will not occur with the primary reason being the domestic deregulation.

The data provided in Figure 4-2 show three distinct breaks at approximately 1500, 3000, and 4200 kilometers. Representative city-pairs are noted in the figure to assist in visualizing the types of routes involved with the respective range breaks. It is anticipated that in the coming years there will be a proliferation of the number of cities served due to an expansion of the networks of established air cargo airlines and the entry of new airlines who prove their capability. The result of this expansion will be an increase in the quantity of goods flown over stages less than 3000 kilometers in length. It is anticipated that it will take 3 to 5 years for the domestic situation to settle out. Over this period there will be a 15 percent increase in the number of cities served at stage lengths of less than 3000 kilometers.

Due to multilateral agreements, such as Bermuda II, future changes in the international scene are less apparent. These agreements can affect such operational factors as frequency, gauge change, and fifth-freedom cargo throughput. These and other factors will in turn affect the variation in cargo volume with stage length.

The variation of cargo flow with range for the U.S. international network is shown in Figure 4-3. There has been a gradual increase in average range over the years noted. It is anticipated that this will change little over the considered time period. In the event there is a revision of attitudes toward international operation relative to such affecting factors

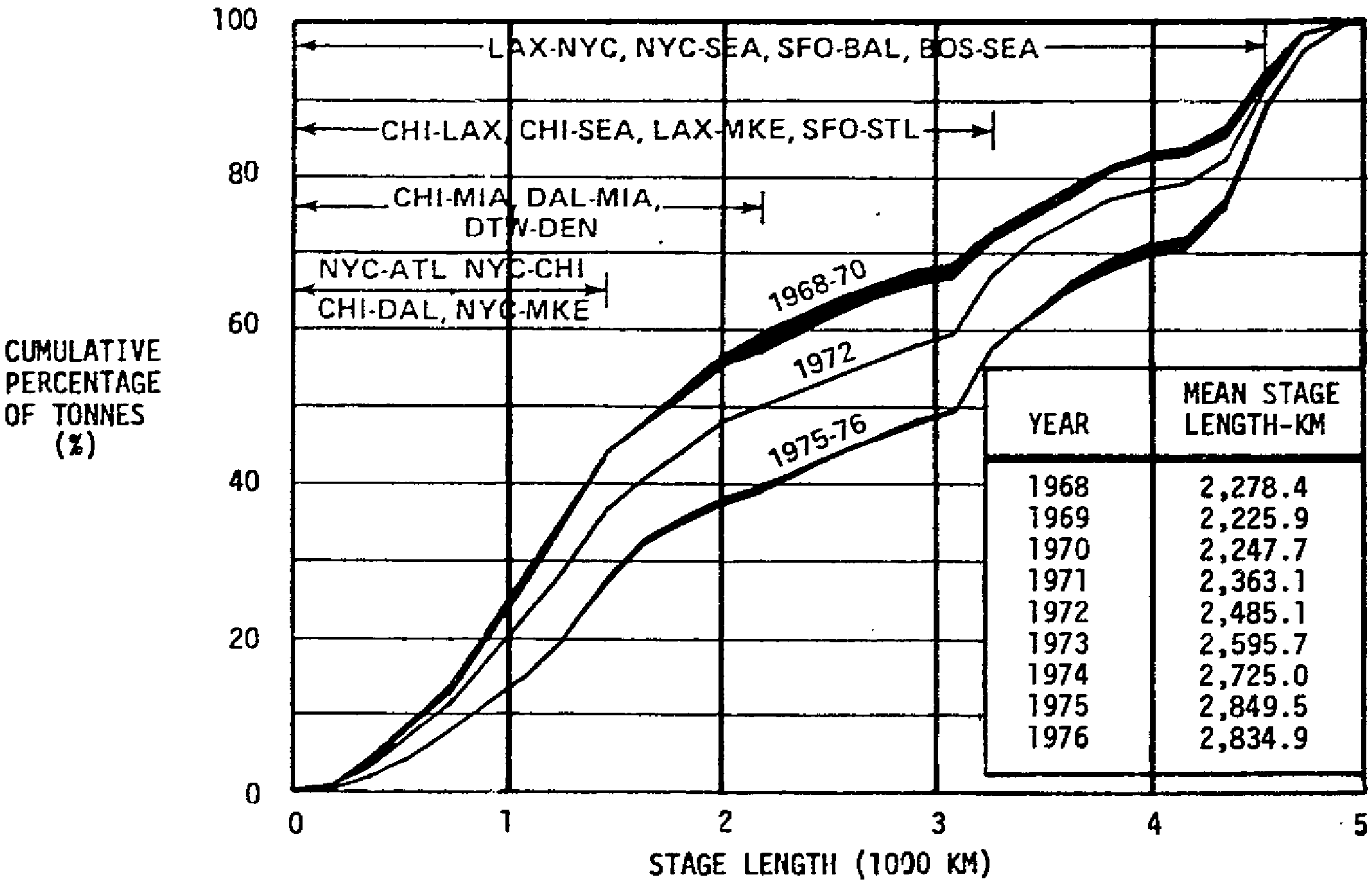

Figure 4-2. Variation of Cargo Flow with Stage Length for the Domestic Air Network

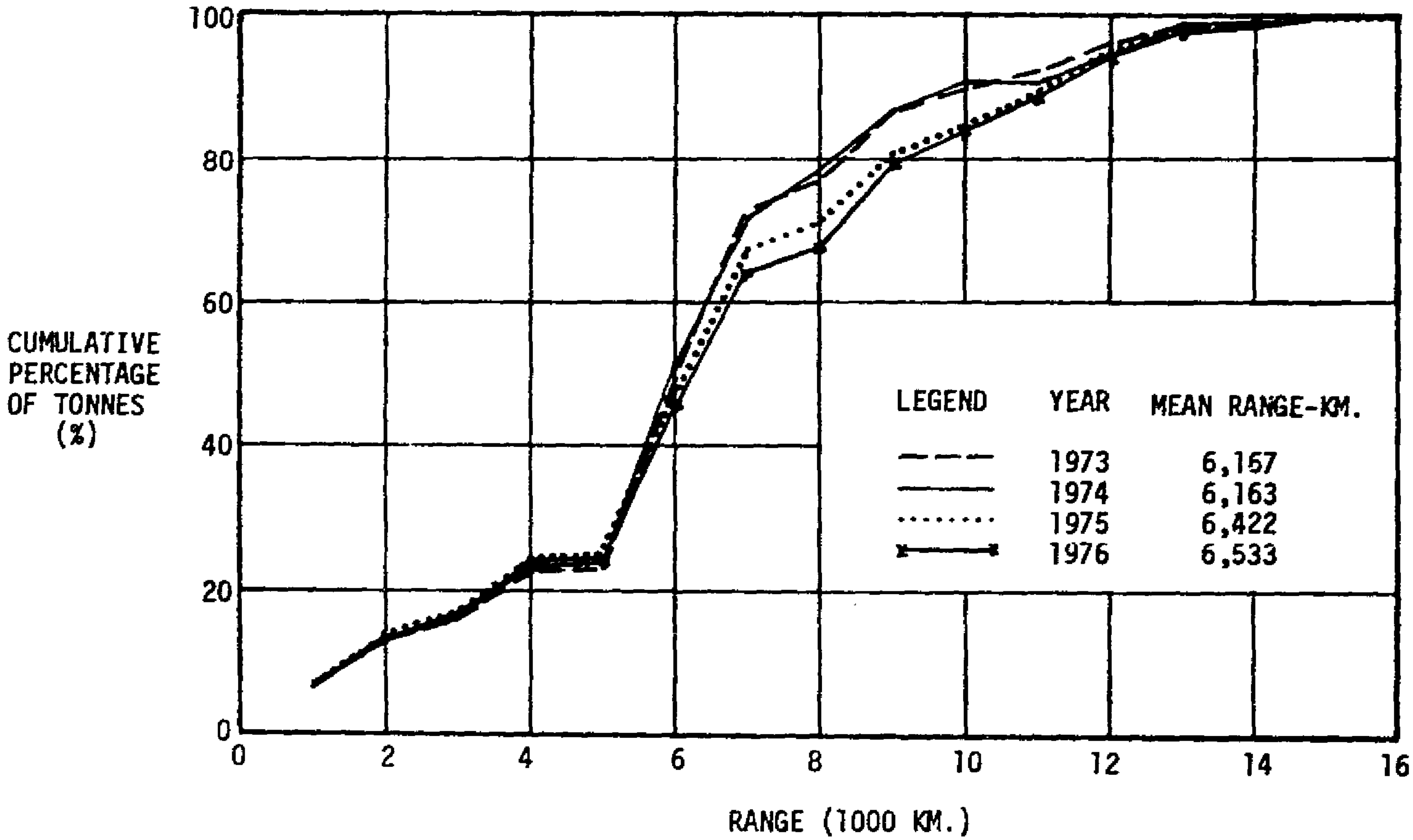

Figure 4-3. Variation of Cargo Flow with Range for U.S. International Network

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as fifth-freedom rights, there should be an accompanying increase in cargo flow over range less than 5000 kilometers. Changes in the principles of bilateral agreements will open the door for network revisions employing the concepts of hub-spoke and itinerary routing. As pointed out in the discussion that follows, these and other routing schemes can have a favorable impact relative to the back-haul problem.

Hub concept. - In the hub-spoke concept, cargo from outlying cities or regions is forwarded to a central point, the hub, where it is consolidated and proceeds to its destination either in the same or perhaps larger aircraft. The spokes need not be served by aircraft only but may employ surface transport alone or in combination. While this concept is already employed domestically to various levels of sophistication and is expected to expand considerably under deregulation, the future potential appears to be greater in the U.S. international market.

One of the primary problems prevalent in international flow is the imbalance between air exports and imports. While one possible solution is a concentrated sales effort to bring the flow into balance, another approach is to revise the routing so as to minimize the tonne-kilometers flown at reduced load factor. The potential of this latter approach was investigated on the basis of United States export and import trade with a developed market, France; a developing market, South America; and a high-growth market, Japan.

The quantities of air cargo that moved between the hub countries, United States, France, Colombia, and Japan during 1976 are shown in the boxes adjacent to the major direction arrows in Figure 4-4. The hub cities are New York, San Francisco, Paris, Bogota, and Tokyo. The flow imbalances are shown by the numbers above the boxes indicating a 90 percent imbalance in exports to France and 40 and 120 percent imbalances in imports from Colombia and Japan respectively. Combining the hub and spoke flows, we obtain the quantities noted in the solid circles. These data show that, at least for 1976, the hub would have provided some relief to the back-haul problem, reducing the United States to France imbalance from 90 to 30 percent. In the case of Colombia, the imbalance shifted from United States imports to exports with an accompanying relatively small change in magnitude from 40 to 30 percent.

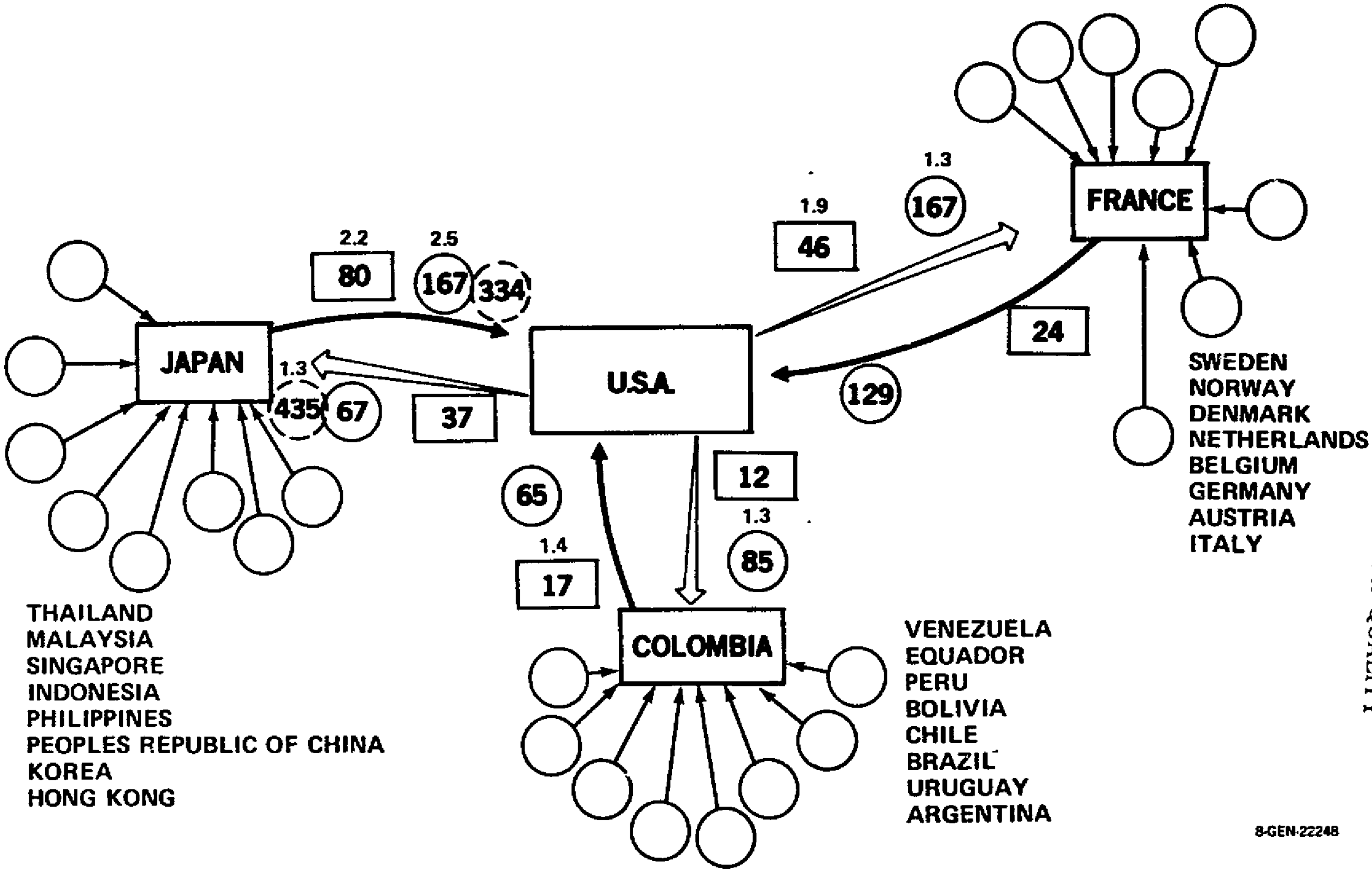

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Figure 4-4. Hub Concept — Backhaul Balance (1000 Tonnes)

This shift in directional imbalance, combined with magnitudes involved, points to the possibility that with a reasonable increase in sales effort this hub market could have been equalized.

In the case of United States-Japan, the case for the hub concept does not appear favorable since combining the flows would have increased the United States import imbalance from 120 percent to 150 percent in 1976. However, looking out into the future to the year 1990 shows a much improved situation. Utilizing the forecasts developed in Section 2 to estimate the growth of the United States-Japan air cargo market and a comparable 333 percent increase for the identified hub markets provides the export-import levels shown in the dashed circles. Under these future conditions, the imbalance has decreased from 150 percent to 30 percent and shifted from United States imports to exports. This behavior indicates that sales working in unison with the implementation of the hub spoke concept could do much to relieve back-haul problems in the future.

The adoption of either or both the hub and itinerary concepts would establish aircraft requirements differing considerable from those for normal international ranges. Aircraft to serve the many outlying areas would require less payload capacity and reduced range. The latter would undoubtedly be a compromise for the characteristics of the many hub systems to be served. However, such plane change would come under the "gauge change" stipulations of the applicable international agreements. Some of these regions could undoubtedly be served better by aircraft requiring less takeoff and landing distances. In addition, the proliferation of the hub concept will increase the market for larger aircraft that are compatible with the flow and frequency of considered hubs.

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SECTION 5

FUTURE MODE CHOICE DECISIONS AND COMMODITY AIR ELIGIBILITY

An important factor in determining the future growth of the air cargo market is the decision process employed by the shipper or consigner and the related air eligibility of the commodities entering in future trade. This section addresses the future of the decision process and extends the eligibility discussions contained in Volume 1 of the final report.

Future Mode Choice Decisions

The mode decision process presently employed by large firms is basically sound and correct. They use airfreight to ship emergency and perishable goods when it is appropriate. Large shippers of divertible freight implicitly or explicitly rely on the total distribution cost concept for most mode choice decisions. Consequently, no major change in the large-firm mode-decision process can be foreseen. Shippers of emergency and perishable cargo will continue to use airfreight when it is appropriate. As was discussed in Volume 1, Section 5, some divertible freight will change from surface to air as inventory carrying costs are more completely and accurately allowed for.

Many small firms and some large corporations, particularly in their foreign subsidiaries, base the mode choice decision on tradition or inadequate information. Most of these firms make correct emergency and perishable goods mode choice decisions. However, the total distribution cost concept can be expected to be more widely applied to divertible freight in the future. Application of the total distribution cost concept will result in an increased demand for airfreight in cases where tradition has been determining mode choice, since airfreight is rarely the traditional mode. An increase in the demand for airfreight can also be expected from shippers who have been basing the mode choice decision on incomplete estimates of inventory carrying costs. Only in those cases where shippers presently use airfreight for high-value-per-kilo

goods because transport costs do not substantially increase total shipment value will application of the total distribution cost concept potentially decrease the demand for airfreight. However, it should be emphasized that inventory carrying cost considerations indicate that most high value-per-kilo products should be shipped airfreight.

The apparent cost of airfreight. - Air passenger fares more closely approximate bus and rail passenger fares than airfreight tariffs approximate truck and rail freight tariffs. This often gives shippers the feeling that airfreight is too expensive to consider. The question of justification of these high apparent cost ratios is addressed in this section. Comparative passenger and freight costs by mode are semi-qualitatively analyzed to determine the costs behind these fares and tariffs. The analysis is based on a number of kilos of freight being equivalent to one passenger as derived through value judgement. For example, if 200 kilograms of freight are found to be equivalent to one passenger, then it costs the same to transport 200 kilograms of freight or one passenger at 100 percent vehicle load factor.

Rail line haul cost comparison: One passenger is equivalent to 1000 to 2000 kilograms of freight. This equivalence is based on the following input assumptions:

- One passenger car holds approximately 80 people versus 50 000 to 75 000 kilograms of freight for a boxcar. That is, one passenger is equivalent to from 625 to 937.5 kilograms of freight, excluding all other considerations.

- Heat, lights, air conditioning, conductor, and other services must be provided all passengers. These services often need to be provided for long periods of time. For example, it takes approximately 3 days to travel from Los Angeles to New York by train.

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- Passenger trains are shorter than freight trains. This detracts from the efficiency of passenger trains, especially the fuel and capital efficiency.

- Passenger trains travel faster than freight trains, consequently, they are less fuel efficient.

- Passenger cars cost considerably more than freight cars.

Highway line haul cost comparison: One passenger is equivalent to from 500 to 700 kilograms of freight. This equivalence is based on the following input assumptions:

- The capital and operational costs of a 50 passenger bus approximate those of a 20 000 kilogram truck.

- Heat, lights, air conditioning, and other services must be provided all passengers. These services often need to be provided for long periods of time. For example, it takes approximately 3 days to travel from Los Angeles to New York by bus.

Air line haul cost comparison: Air passenger freight equivalence varies by line-haul vehicle type. One passenger is equivalent to from 120 to 160 kilograms of freight on a DC-8. The corresponding DC-10 equivalence is from 180 to 230 kilograms of freight per passenger. The following information was used to develop the equivalence ranges:

- A comparison of freighter versus passenger-carrying capacities by air line-haul vehicle type. This comparison was based on the following assumptions:

    - An airline passenger with baggage weighs 90.0 kilograms on the average.

    - An airline passenger's baggage occupies 0.1 cubic meter on the average.

- Airfreight has an on-board density of 141 kilograms per cubic meter exclusive of tare weight.

- The comparison ratios developed in this comparison are presented below:

  - DC-8-61 - One passenger is equivalent to 119 to 133 kilograms of freight, depending on passenger seating configuration.

  - DC-8-61 - One passenger is equivalent to 141 to 156 kilograms of freight, depending on passenger seating configuration.

  - DC-10-30 - One passenger is equivalent to 184 to 230 kilograms of freight, depending on passenger seating configuration.

- Food, hostess, and other services must be provided all passengers. These services need to be provided for only short periods of time. For example, it takes approximately 5 hours to travel from Los Angeles to New York by air.

- The capital outlay for a freight aircraft is larger than the capital outlay for the corresponding passenger version.

- Freight aircraft use more fuel than passenger aircraft because of high gross take-off weights.

Summary: The number of kilograms of freight equivalent to each passenger is lower for the air mode than either the rail or highway modes. Consequently, airfreight tariffs must be higher relative to air passenger fares than other mode freight tariffs are relative to their respective passenger fares, given that fares and tariffs are based on costs. However, wide-body aircraft are helping to improve the equivalence ratios for freight aircraft as can be seen by the DC-10-30 entry compared to the DC-8 entries in Table 5-1.

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TABLE 5-1

FREIGHT, PASSENGER EQUIVALENCE RATIOS BY MODE

Linc Haul Vehicle	Kilos of Freight Equivalent To One Passenger
Train	1000 - 2000
Highway Vehicles	500 - 700
DC-8-61	120 - 135
DC-8-63	140 - 155
DC-10-30	185 - 230

Commodity Air Eligibility

Commodities can be considered air eligible by virtue of perishibility due to their physical characteristics or by virtue of their importance to the total production/marketing scheme which can place them in the category of an emergency shipment. This section will briefly outline the anticipated potential of these two categories of commodities and will discuss the importance of the ratio of shipping cost to product value as an indicator of divertability.

Perishable and emergency. - A good dependable airfreight system makes it possible to produce perishable products thousands of miles from the market. For example, eels are born in North Carolina then shipped by air to Japan where they are grown and sold. As more shippers learn to use the airfreight system in this manner and as the airfreight network expands, the perishable sector demand for airfreight will increase.

The largest and most developed airfreight sector is usually considered to be the emergency freight sector. Since this sector is large and well developed, future growth is usually expected to be moderate. This is not necessarily true for two reasons. First, as the products of modern industry become more widespread and industry itself diversifies, the size of the emergency freight sector

increases. This demand is conceptually very elastic even though no statistical measures of the market or its elasticity have yet been devised. Second, a good dependable airfreight system makes it possible to inventory products needed in emergency situations in less places. For example, Caterpillar Tractor has chosen to provide spare parts for Caterpillars in Africa from Illinois. As more shippers learn to use the airfreight system in this manner and as the airfreight network expands, the emergency sector demand for airfreight will increase.

The process of learning to use airfreight and expansion of the services provided by airfreight carriers are important in terms of airfreight maturity. It usually takes 75 years for a transportation sector to mature, and airfreight has a long way to go. Consequently, sizeable perishable and emergency sector increases can be expected by 1990 even though these sectors are usually considered to be the most highly developed segments of the airfreight market.

Divertable. - The data presented in Sections 1 and 2 of Volume I were analyzed to investigate future divertible sector air eligibility. Volume 2 of the CLASS final report outlines the results of the United Airlines' 1969 survey, the UK Civil Aviation Authority survey, and the case studies performed for the CLASS study. These studies all emphasize the importance of airfreight for emergency shipments. An analysis of airfreight data indicates that these studies are not all encompassing. Commodity value per kilo is strongly correlated with the mode used. This is indicative of either dependence on the total distribution cost concept or less concern for transportation costs as value per kilo increases. Shippers who use the total distribution cost concept substitute air transportation for inventory carrying costs as shipment value per kilo increases.

Some shippers are less concerned about air transportation costs as value per kilo increases since air transportation costs do not appreciably increase shipment value for high-value-per-kilo shipments. Examples of how transport costs increase the total shipment value were prepared to illustrate this point. Transport costs by truck and air for a 2270 kilo shipment of electrical machinery from San Francisco to New York were obtained from Section 4

of Volume I. The value of the shipment was obtained by assuming commodity values at $20, $15, $10 and $5 per kilo. The total shipment value is the sum of the value of the shipment and the transport costs. Transportation costs were then calculated as a percent of the total shipment value.

The same approach was used to compare 2270 kilo sea and air shipments of electrical machinery between London and New York and Tokyo and Frankfurt (Hamburg in the case of sea). Tables 5-2 through 5-5 and Figure 5-1 show the rapid percentage increase in air transport costs represented as a percent of total shipment value when the commodity value/kilo declines.

A comparison of U.S. air trade data with the Far East is presented in Table 5-6. It shows that as the commodity value/kilo declines, the air percent of total exports declines. Figure 5-2 shows the percent of air shipments over the value ranges for all of U.S. exports to Far East destination countries. It clearly indicates a sharp decline as commodity value/kilo decreases, particularly when the less than $10/kilo range is reached.

The tendency to ship high-value commodities by air is again illustrated by Table 5-7. This table is a listing of selected commodities shipped from the United States to Bolovia, Brazil, the United Kingdom and West Germany for 1976. The selection process was based upon significant tonnage moving by sea and valued at $10/kilo or above. Air transport of the identical commodities was identified, and the value/kilo and tonnage shipped was compared with the sea data. These data are summarized in Table 5-8. Again, high value seems to be characteristic of commodities shipped by air.

Density. - From 1967 to 1970 Douglas sponsored an in-house program for the analysis of advanced cargo systems. Top priority was given to the development of a warehouse density data bank by commodity. Aircraft design density can be established from warehouse cargo density, developed for the relative commodity mix over a route and appropriately modified to consider unitization and on-board loading. A report was published as the "Warehouse Cargo Density Report" and is an available comprehensive source listing produce densities.

TABLE 5-2

SAN FRANCISCO — NEW YORK

ELECTRICAL MACHINERY

Commodity Value/kg ($)	Mode	Value of 2270 Kilo Shipment ($)	Transportation Charge* ($)	Total Shipment Value ($)	Transportation Cost As Percent Of Total Shipment Value
20	Air Truck	45 400	2 286 659	47 686 46 059	4.8 1.4
15	Air Truck	34 050	2 286 659	36 336 34 709	6.3 1.9
10	Air Truck	22 700	2 286 659	24 986 23 359	9.1 2.8
5	Air Truck	11 350	2 286 659	13 636 12 009	16.8 5.5

* Air: $1.0072/kg
Truck: $ .2905/kg

TABLE 5-3

LONDON — NEW YORK

ELECTRICAL MACHINERY

Commodity Value/kg ($)	Mod	Value of 2270 Kilo Shipment ($)	Transportation Charge* ($)	Total Shipment Value ($)	Transportation Cost As Percent Of Total Shipment Value
20	Air Sea	45 400 45 400	2 500 817	47 900 46 217	5.2 1.8
15	Air Sea	34 050 34 050	2 500 817	36 550 34 867	6.8 2.3
10	Air Sea	22 700 22 700	2 500 817	25 200 23 517	9.9 3.5
5	Air Sea	11 350 11 350	2 500 817	13 850 12 167	18.0 6.7

* Air: $1.1013/kg
Sea: $0.3599/kg

TABLE 5-4

TOKYO — FRANKFURT (HAMBURG BY SEA)

ELECTRICAL MACHINERY

Commodity Value/kg ($)	Mode	Value of 2270 Kilo Shipment ($)	Transportation Charge* ($)	Total Shipment Value ($)	Transportation Cost As Percent Of Total Shipment Value
20	Air	45 400	9 656	55 056	17.5
	Sea	45 400	584	45 984	1.3
15	Air	34 050	9 656	43 706	22.1
	Sea	34 050	584	34 634	1.7
10	Air	22 700	9 656	32 356	29.8
	Sea	22 700	584	23 284	2.5
5	Air	11 350	9 656	21 006	46.0
	Sea	11 350	584	11 934	4.9

* Air: $4.2537/kg
Sea: $0.2572/kg

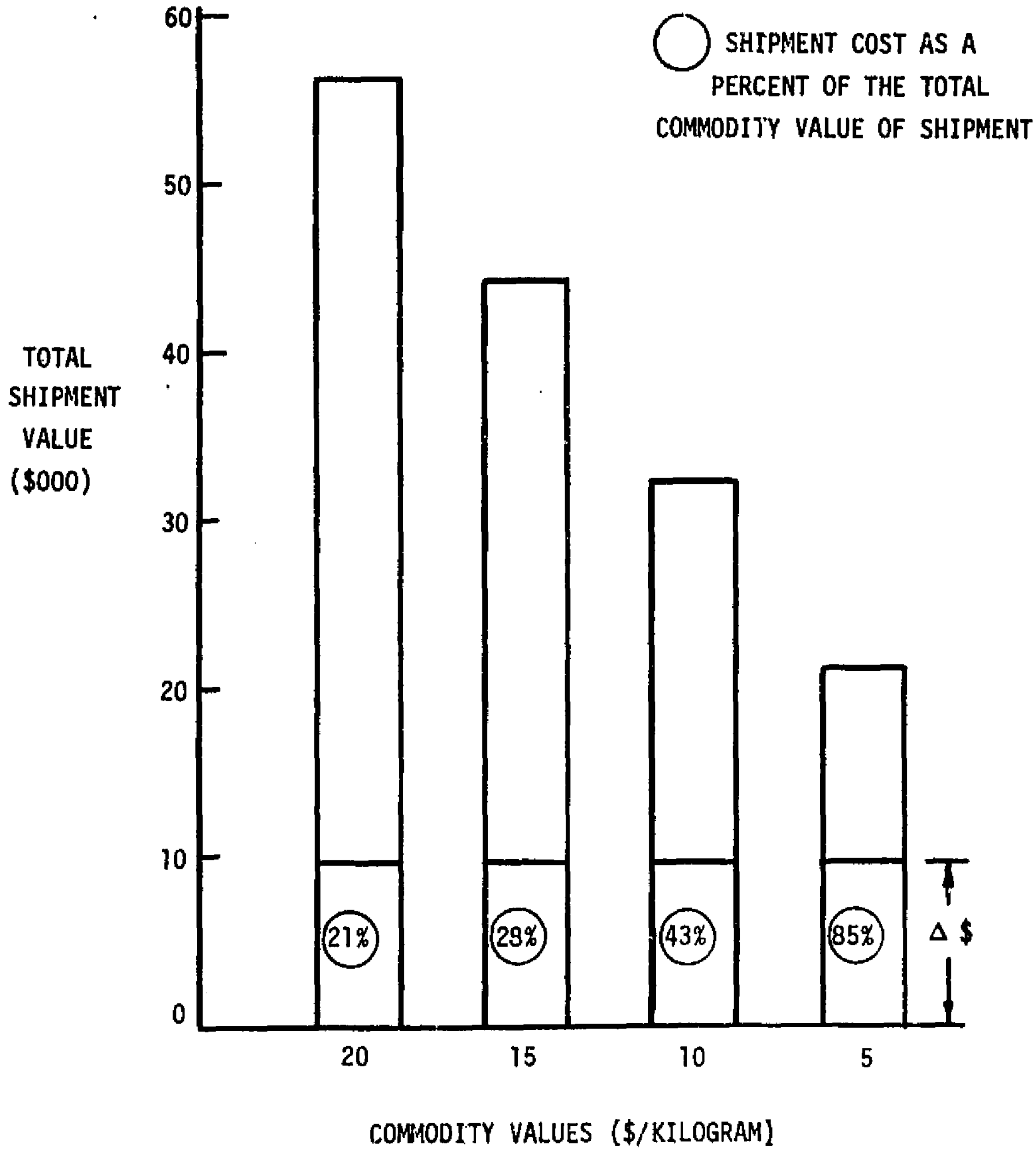
TABLE 5-5

PERCENT INCREASE IN SHIPMENT VALUE

ADDED BY TRANSPORT COST

(ELECTRICAL MACHINERY)

Market	Commodity Value/kg ($)	Percent Increase	
		Air	Surface
SFO-NYC	20	5	1
	15	7	2
	10	10	3
	5	20	6
LON-NYC	20	6	1.7
	15	7	2.4
	10	11	4
	5	22	7
TYO-FRA	20	21	1
	15	28	2
	10	43	3
	5	85	5



Δ $ = SHIPPING COST

Figure 5-1. General Commodity Rate for 2270-Kilogram Shipment by Air for Electrical Machinery at $4.2537/kg, Tokyo to Frankfurt

TABLE 5-6

COMPARISON OF U.S. AIR TRADE DATA WITH THE FAR EAST

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AIR PERCENT OF TOTAL EXPORT DOLLARS

Destination Country	Commodity U.S. $-Value/Kilogram Range								
	Over 20.0	19.9 15.0	14.9 10.0	9.9 5.0	4.9 4.0	3.9 3.0	2.9 2.0	1.9 1.0	0.9 0.0
Thailand	71.9%	18.4%	8.6%	18.6%	0.3%	0.1%	0.2%	0.2%	0.0%
Malaysia	96.5	27.2	50.6	8.2	1.8	0.3	0.7	0.3	0.2
Singapore	93.9	73.0	71.4	9.8	0.6	1.4	0.1	0.1	0.1
Indonesia	86.9	78.3	52.3	19.5	0.2	0.1	0.2	0.1	0.1
Philippines	86.5	62.4	26.7	14.6	1.8	0.4	0.4	0.2	0.0
Republic of Korea	91.3	24.1	4.4	9.3	3.3	0.1	8.9	0.4	0.0
Hong Kong	94.3	11.2	22.2	6.0	7.0	0.6	1.3	0.3	0.3
Republic of China	59.7	55.4	66.8	2.4	3.5	2.1	0.3	0.4	0.0
Japan	81.4	58.9	26.9	10.5	20.6	2.9	0.8	0.7	0.1
Australia	84.4	26.3	31.8	21.6	0.6	0.4	0.3	0.2	0.0
(United Kingdom-ref.)	95.0	80.7	69.4	35.0	7.5	5.1	1.5	2.2	0.7

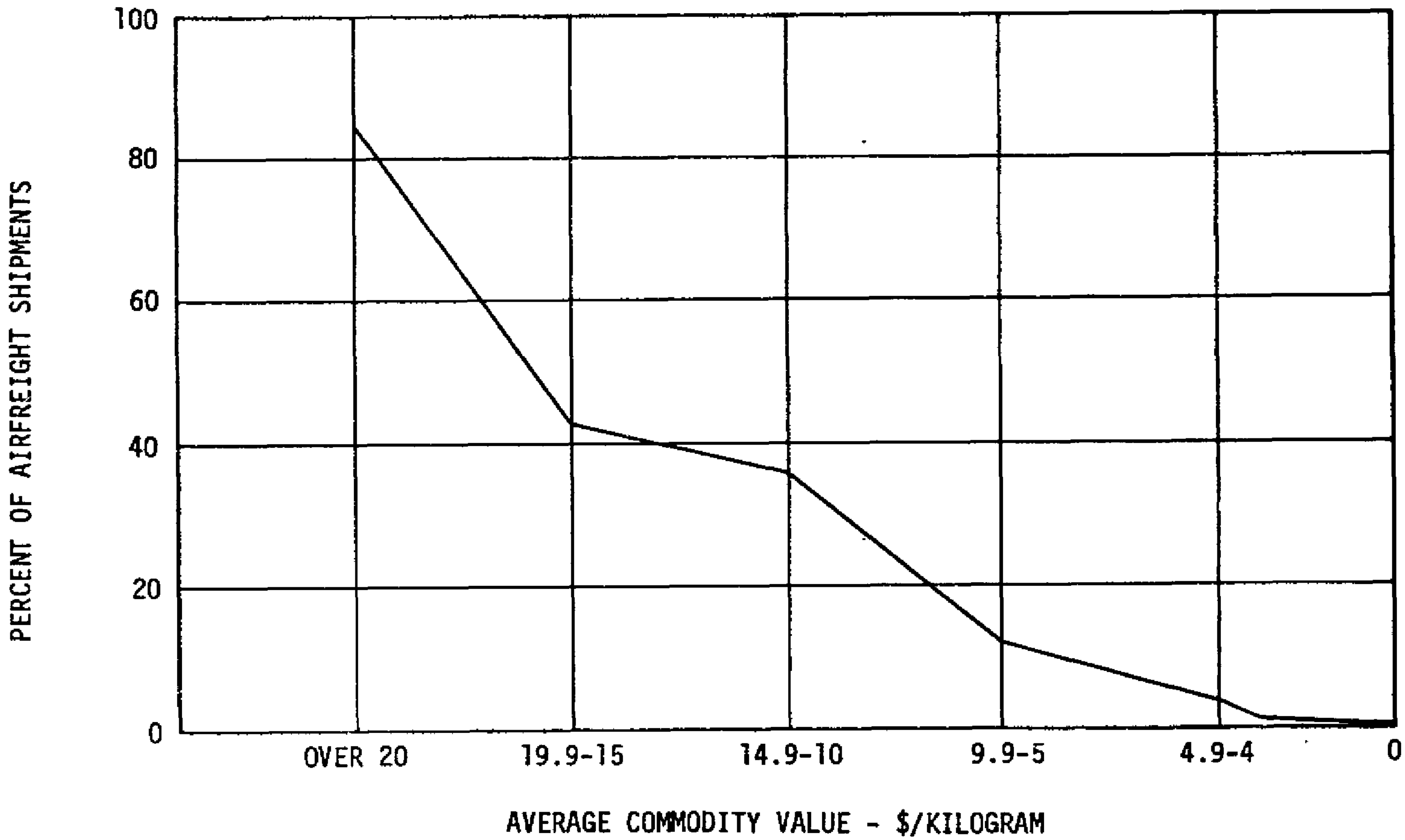

Figure 5-2. Commodity Value in U.S. Air Trade to the Far East

TABLE 5-7

SPECIFIC COMMODITIES TRANSPORTED BY AIR FROM THE UNITED STATES

TO SELECTED COUNTRIES COMPARED WITH SIMILAR COMMODITIES SHIPPED BY SEA, 1976

Destination	Commodity Description	Air Transport		Sea Transport		Total Kilos (000)	Air Percent of Total Kilos
		Value in $/kg	Kilos Shipped (000)	Value ($/kg)	Kilos Shipped (000)		
Bolivia	Internal Combustion Engines, Other	12.16	68.5	7.50	291.9	360.4	19.0
	TV Broadcasting Receivers	9.93	212.6	10.5	615.9	828.5	25.7
	Electrical Starting Ignition Equipment	10.17	2.0	8.53	46.9	48.9	4.1
Brazil	Other Electrical Measuring Equipment	68.48	223.9	23.16	583.3	807.2	38.4
	Sewing Machines	132.04	10.7	20.12	198.1	208.8	5.1
	Liquid & Gas Measuring Instruments	29.94	66.4	18.88	197.0	263.4	25.2
	Aircraft Parts	57.74	26.9	17.59	267.3	325.0	8.3
	Motion Picture Film	17.95	115.7	17.46	806.5	922.2	12.5

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TABLE 5-7 - Continued

SPECIFIC COMMODITIES TRANSPORTED BY AIR FROM THE UNITED STATES

TO SELECTED COUNTRIES COMPARED WITH SIMILAR COMMODITIES SHIPPED BY SEA, 1976

Destination	Commodity Description	Air Transport		Sea Transport		Total Kilos (000)	Air Percent of Total Kilos
		Value in $/kg	Kilos Shipped (000)	Value ($/kg)	Kilos Shipped (000)		
Brazil (cont.)	Photograph Equipment NES	22.56	153.6	16.45	1 282.2	1 435.8	10.7
	Steam Engines Without Boilers	40.15	7.1	15.76	426.0	466.2	8.6
	Medical Instruments and Appliances	45.58	128.4	14.71	141.0	269.4	47.7
	Essential Oils and Resinoids	31.90	3.2	14.44	159.7	162.9	2.0
	Drawing, Measuring Instruments	40.59	10.1	14.32	172.2	182.3	5.5
	Packaging and Container Filling Machinery	40.59	12.4	12.12	315.3	327.7	3.8
	Interchangeable Tools	58.04	26.9	11.99	372.8	399.7	6.7

TABLE 5-7. - Continued

SPECIFIC COMMODITIES TRANSPORTED BY AIR FROM THE UNITED STATES

TO SELECTED COUNTRIES COMPARED WITH SIMILAR COMMODITIES SHIPPED BY SEA, 1976

Destination	Commodity Description	Air Transport		Sea Transport		Total Kilos (000)	Air Percent of Total Kilos
		Value in $/kg	Kilos Shipped (000)	Value ($/kg)	Kilos Shipped (000)		
Brazil (cont.)	Optical Glass, Elements and Blanks	12.27	11.7	11.97	170.2	181.9	6.9
	Machine Tool Parts	59.86	58.5	10.02	720.1	778.6	7.5
United Kingdom	Aircraft Parts	89.60	794.5	45.18	370.0	1 164.5	68.2
	Vitamins	22.37	22.8	24.18	66.3	89.1	25.6
	Photographis Cameras	23.08	350.1	21.65	322.7	672.8	52.0
	Fountain Pen, Pencils, Holders	13.06	179.0	19.20	266.0	445.0	40.2
	Other Electrical Measuring Equipment	69.77	1 264.6	18.92	400.1	1 664.7	76.0
	Steam Engines Without Boilers	33.50	24.5	17.87	348.3	372.8	6.6
	Calculating Machines	29.75	131.4	17.29	109.0	240.4	54.7

TABLE 5-7. - Continued

SPECIFIC COMMODITIES TRANSPORTED BY AIR FROM THE UNITED STATES

TO SELECTED COUNTRIES COMPARED WITH SIMILAR COMMODITIES SHIPPED BY SEA, 1976

Destination	Commodity Description	Air Transport		Sea Transport		Total Kilos (000)	Air Percent of Total Kilos
		Value in $/kg	Kilos Shipped (000)	Value ($/kg)	Kilos Shipped (000)		
United Kingdom (Cont.)	Gramaphones, Tapes, Recorders	54.87	357.4	16.83	481.9	839.3	42.6
	Motion Picture Film	19.79	335.5	16.03	1 352.0	1 687.5	19.9
	Razors and Razor Blades	14.00	54.2	14.78	353.7	407.9	13.3
	Photographic Equipment NES	17.74	951.3	13.37	684.6	1 635.9	58.2
	Gas Turbines	79.03	80.4	12.78	702.4	782.8	10.3
	Parts of Office Machinery NES	48.07	4655.3	12.50	589.8	5 245.1	88.8
	Synthetic Perfume and Flavoring	22.62	66.3	12.18	293.4	359.7	18.4
	Essential Oils and Resinoids	17.64	3.5	11.88	1 398.2	1 401.7	0.02

TABLE 5-7. - Concluded

SPECIFIC COMMODITIES TRANSPORTED BY AIR FROM THE UNITED STATES

TO SELECTED COUNTRIES COMPARED WITH SIMILAR COMMODITIES SHIPPED BY SEA, 1976

Destination	Commodity Description	Air Transport		Sea Transport		Total Kilos (000)	Air Percent of Total Kilos
		Value in $/kg	Kilos Shipped (000)	Value ($/kg)	Kilos Shipped (000)		
United Kingdom (Cont.)	Packaged Containers Filling Machinery	23.98	300.7	10.79	692.0	992.7	30.2
	Interchangeable Tools	33.12	242.2	10.38	1 426.8	1 669.0	14.5
West Germany	Fur Skins, Undressed	60.73	378.5	39.65	344.2	722.7	52.4
	Other Telecom Equip.	93.00	669.6	34.54	230.4	900.0	74.4
	Aircraft Parts	103.69	1 188.6	29.02	603.5	1 792.1	66.3
	Other Electrical Measuring Equip.	65.01	1 472.9	20.11	584.5	2 057.4	71.6
	Parts & Accessories of Controlling	55.38	944.6	14.60	211.2	1 155.8	81.7
	Gas Turbines, Other Than For Aircraft	48.62	176.9	12.51	834.7	1 011.6	17.5
	Photographic Equip. NES	16.14	2 521.4	11.26	1 374.0	3 895.4	64.7
	Parts of Office Machinery	49.93	4 578.0	10.53	1 024.6	5 602.6	81.7

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TABLE 5-8
1976

SUMMARY OF THE VALUE RANGE OF IDENTICAL COMMODITIES SHIPPED FROM THE UNITED STATES BY AIR AND SURFACE TO SELECTED COUNTRIES (EXCLUDING BOLIVIA), 1976

Commodity Value Range ($/kg)	Air Transport (Value Range: $132.04 to $14.00/kg)			Sea Transport (Value Range: $45.18 to $10.02/kg)		
	Number of Commodities Within Value Range	%	Commodity Mean Value ($/kg)	Number of Commodities Within Value Range	%	Commodity Mean Value ($/kg)
Over $40	21	56	64.80	1	3	45.18
30 - 40	3	7	32.84	2	5	37.10
20 - 30	7	17	24.90	6	15	23.21
10 - 20	8	20	16.07	30	77	14.31

In order to determine the characteristics of air cargo commodities a series of terminal surveys in the United States and Europe was conducted to provide pertinent characteristics of air cargo and cargo module (pallets and ATA Type A container) loads. One of the findings of these surveys showed that the warehouse density was reduced to 54 percent when products were loaded on pallets or in containers and that the optimum achievable density was approximately 70 percent. Tables 5-9 through 5-11 list the leading domestic US international, and foreign commodities transported by air as reported in Section 1 of Volume 1. This table compares warehouse density with the achieved and optimum loaded densities for traffic moving between selected U.S. city-pairs.

The IATA carriers have a "...." rule which establishes a pivot point of 142 kilograms per cubic meter (8.9 pounds per cubic foot) for rate-making purposes. Products with densities less than 142 kilograms per cubic meter are rated as if they were of that density. The commodities selected and shown in Table 5-7 were evaluated in terms of their warehouse density and probable loaded density (54 percent of warehouse density) with results presented, unordered, in Table 5-12. The observation can be made that the airlines as well as shippers need to reassess the capability to increase the weight of on-board loads through more efficient handling and packaging procedures. Increased loaded density would be reflected in lower tariffs which would be a move towards reaching surface tariffs.

Tables 5-13, 5-14, and 5-15 were extracted from data prepared for Section 1 of Volume 1 and provide a listing of the sea mode U.S. exports and imports between selected country and city/country pairs at commodity values over \$5, \$10, and \$15 per kilo. One can see that as commodity values increase, the tonnage decreases significantly. Nevertheless, a combination of reduced transit cost and increased capacity could create a substantial potential for air penetration of the surface mode.

TABLE 5-9

U.S. DOMESTIC

LEADING COMMODITIES TRANSPORTED BY AIR

Description	Mean Warehouse Density (kg/m^3)	Loaded Density: Achieved 54 Percent Warehouse (k/m^3)	Loaded Density: Optimum 70 Percent Warehouse (k/m^3)
Machinery Parts	283.55	153.12	198.49
Cut Flowers	107.33	57.96	75.13
Electrical Products	219.47	118.51	153.63
Wearing Apparel	129.76	70.07	90.83
Printed Matter	522.25	282.02	365.58
Auto Parts, Accessories	230.69	124.57	161.48
Aircraft Parts	169.81	91.70	118.87
General Hardware	88.11	47.58	61.68
Metal Products	410.11	221.46	287.08
Phonograph Records, Tapes	262.73	141.87	183.91
Fresh Produce	310.79	167.83	217.55
Photographic Film	330.01	178.21	231.01
Average	255.4	137.9	178.3

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TABLE 5-10

INTERNATIONAL AIR CARGO - WAREHOUSE DENSITY VS LOADED DENSITY

Cargo Movement Regions	Mean Warehouse Density (kg/m^3)	Loaded Density	
		Achieved 54 Percent Warehouse (kg/m^3)	Optimum 70 Percent Warehouse (kg/m^3)
United States Exports to:			
Africa	293.49	158.43	205.44
Asia & Far East	220.43	119.63	154.30
Australia, New Zealand	274.90	148.45	192.43
Canada	322.64	174.23	225.85
Eastern Europe	317.84	171.63	222.49
Greeland, Iceland	307.10	165.83	214.97
Latin America	240.94	130.11	168.66
Mid East	280.19	151.30	196.13
Western Europe	229.41	123.88	160.59
Total U.S. Exports	238.86	128.98	166.85
United States Imports from:			
Africa	159.88	86.34	111.92
Asia & Far East	211.46	114.19	148.02
Australia, New Zealand	372.95	201.39	261.07
Canada	305.34	164.88	213.74
Eastern Europe	265.29	143.26	185.70
Greeland, Iceland	156.52	84.52	109.56
Latin America	271.86	146.80	190.30
Mid East	120.79	65.23	84.55
Western Europe	178.30	53.40	124.81
Total U.S. Imports	187.43	101.21	131.20

TABLE 5-11
FOREIGN AIR CARGO - WAREHOUSE DENSITY VS LOADED DENSITY

Cargo Movement Regions	Mean Warehouse Density (kg/m^3)	Loaded Density: Achieved 54 Percent Warehouse (kg/m^3)	Loaded Density: Optimum 70 Percent Warehouse (kg/m^3)
Western Europe Exports to:			
Africa	262.57	141.79	183.80
Asia & Far East	299.41	161.68	161.68
Australia, New Zealand	330.01	178.21	231.01
Canada	188.56	101.82	101.82
Eastern Europe	389.77	210.48	210.48
Greenland, Iceland	258.08	139.36	180.66
Latin America	324.01	174.97	226.81
Mid East	273.78	147.84	191.65
United States	178.30	96.28	124.81
Total Western Europe Exports	206.98	111.77	144.89
Western Europe Imports From:			
Africa	230.05	124.23	161.04
Asia & Far East	259.20	139.97	181.44
Australia, New Zealand	202.17	109.17	141.52
Canada	198.65	107.27	139.06
Eastern Europe	282.43	152.51	197.70
Greeland, Iceland	392.33	211.86	274.63
Latin America	212.27	114.63	148.59
Mid East	247.35	133.57	173.15
United States	229.41	123.88	160.59
Total Western Europe Imports	229.25	123.80	160.48

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TABLE 5-12

SPECIFIC POTENTIAL AIR TRANSPORT COMMODITIES
MOVING BY SURFACE FROM THE UNITED STATES
(By SITC Designator), 1976

Destination	Commodity Description	Value $/kg	Kilos Transported (000)	Mean Warehouse Density (kg/m^3)	Loaded Density (54%)
Bolivia	TV Broadcast Receiver (72410)	10.05	615.9	144.2	77.9
	Electrical Starting Ignition Equipment (72941)	8.53	46.9	358.8	193.8
	Internal Combustion Engines (71150)	7.50	291.9	471.0	254.3
Brazil	Other Electrical Measuring Equipment (72952)	23.16	583.3	200.3	108.1
	Sewing Machines (71730)	20.12	198.1	261.1	141.0
	Liquid and Gas Measuring Instruments (86197)	18.88	197.0	378.1	204.2
	Aircraft Parts (73492)	17.59	267.3	169.8	91.7
	Motion Picture Film (86246)	17.46	806.5	NA	NA
	Photographic Equipment NES (86169)	16.45	1282.2	203.5	109.9

TABLE 5-12. - Continued

SPECIFIC POTENTIAL AIR TRANSPORT COMMODITIES MOVING BY SURFACE FROM THE UNITED STATES (By SITC Designator), 1976

Destination	Commodity Description	Value $/kg	Kilos Transported (000)	Mean Warehouse Density (kg/m^3)	Loaded Density (54%)
Brazil (cont.)	Steam Engines Without Boilers (71132)	15.76	426.0	368.5	199.0
	Medical Instruments and Appliances (86171)	14.71	141.0	136.2	73.5
	Essential Oils and Resinoids (55110)	14.44	159.7	881.1	475.8
	Drawing, Measuring Instruments (86193)	14.32	172.2	450.2	243.1
	Packaging & Container Filling Machinery (71962)	12.12	315.3	147.4	79.6
	Interchangeable Tools (69524)	11.99	372.8	793.0	428.2

TABLE 5-12. - Continued
SPECIFIC POTENTIAL AIR TRANSPORT COMMODITIES
MOVING BY SURFACE FROM THE UNITED STATES
(By SITC Designator), 1976

Destination	Commodity Description	Value $/kg	Kilos Transported (000)	Mean Warehouse Density (kg/m^3)	Loaded Density (54%)
Brazil (Cont.)	Optical Glass, Elements & Blanks (66420)	11.97	170.2	1 066.9	576.1
	Machine Tool Parts (71954)	10.02	720.1	184.2	99.5
United Kingdom	Aircraft Parts (73492)	45.18	370.0	169.8	91.7
	Vitamins (54110)	24.18	66.3	499.8	269.9
	Photographic Cameras (86140)	21.65	322.7	179.4	96.9
	Fountain Pens, Pencils, Holders (89521)	19.20	266.0	398.9	215.4
	Other Electrical Measuring Equipment (72952)	18.92	400.1	200.3	108.1

TABLE 5-12. - Continued

SPECIFIC POTENTIAL AIR TRANSPORT COMMODITIES
MOVING BY SURFACE FROM THE UNITED STATES
(By SITC Designator), 1976

Destination	Commodity Description	Value $/kg	Kilos Transported (000)	Mean Warehouse Density (kg/m3)	Loaded Density
United Kingdom (Cont.)	Steam Engines Without Boilers (71132)	17.87	348.3	368.5	199.0
	Calculating Machines (71420)	17.29	109.0	251.5	135.8
	Gramaphones, Tapes Recorders (89111)	16.83	481.9	195.4	105.5
	Motion Picture Film (86246)	16.03	1 352.0	NA	NA
	Razors & Razor Blades (69603)	14.78	353.7	1 342.5	724.9
	Photographic Equipment NES (86169)	13.37	684.6	203.5	109.9
	Gas Turbines (71160)	12.78	702.4	192.2	103.8

TABLE 5-12. - Continued
SPECIFIC POTENTIAL AIR TRANSPORT COMMODITIES
MOVING BY SURFACE FROM THE UNITED STATES
(By SITC Designator), 1976

Destination	Commodity Description	Value $/kg	Kilos Transported (000)	Mean Warehouse Density (kg/m^3)	Loaded Density
United Kingdom (Cont.)	Parts of Office Machinery NES (71492)	12.50	589.8	197.0	106.4
	Synthetic Perfume and Flavoring (55120)	12.18	293.4	NA	NA
	Essential Oils & Resinoids (55110)	11.88	1 398.2	881.1	475.8
	Package & Container Filling Machinery (71962)	10.79	692.0	147.4	79.6
	Interchangeable Tools (69524)	10.38	1 426.8	793.0	428.2
West Germany	Fur Skins, Undressed (21200)	39.65	344.2	200.3	108.1
	Other Telecom Equipment (72499)	34.54	230.4	221.1	119.4

TABLE 5-12. - Concluded
SPECIFIC POTENTIAL AIR TRANSPORT COMMODITIES
MOVING BY SURFACE FROM THE UNITED STATES
(By SITC Designator), 1976

Destination	Commodity Description	Value $/kg	Kilos Transported (000)	Mean Warehouse Density (kg/m^3)	Loaded Density
West Germany (Cont.)	Aircraft Parts (73492)	29.02	603.5	169.8	91.7
	Motion Picture Film (86246)	21.25	2 591.8	NA	NA
	Other Electrical Measuring Equipment (72952)	20.11	584.5	200.3	108.1
	Parts and Accessories of Controlling Instruments (86199)	14.60	211.2	312.4	168.7
	Gas Turbines, Other Than for Aircraft (71160)	12.51	834.7	192.2	103.8
	Photographic Equipment NES (86169)	11.26	1 374.0	203.5	109.9
	Parts of Office Mach. (71492)	10.53	1 024.6	197.0	106.4

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TABLE 5-13

U.S. 1976 EXPORTS TO SELECTED COUNTRIES
SEA TONNES ONLY

Exports U.S. To:	Commodity Value		
	Over $5/kg	Over $10/kg	Over $15/kg
1. Bolivia	2 364	728	40
2. Brazil	90 895	7 895	4 834
3. United Kingdom	94 120	16 413	7 975
4. France	48 543	8 630	4 129
5. West Germany	70 333	14 941	6 145
6. Italy	29 655	7 285	4 181
7. Iran	51 988	7 547	6 133
8. Indonesia	25 294	10 935	1 392
9. Hong Kong	23 203	3 610	2 045
10. Taiwan	35 395	8 028	3 163
11. Japan	111 660	22 588	14 025
12. Australia	66 108	10 646	4 950
13. Nigeria	21 488	1 085	700
14. South Africa	55 580	3 003	1 798
15. Venezuela	37 655	3 266	1 096
16. Morocco	7 392	205	62
TOTALS..............	771 673	126 805	62 668

TABLE 5-14

U.S. 1976 IMPORTS FROM SELECTED COUNTRIES

SEA TONNES ONLY

Imports to U.S. From:	Commodity Value		
	Over $5/kg	Over $10/kg	Over $15/kg
1. Bolivia	3 143	0	0
2. Brazil	28 913	2 596	2 459
3. United Kingdom	49 177	8 694	6 530
4. France	47 857	18 112	12 297
5. Germany	122 077	20 343	5 312
6. Italy	49 319	4 086	2 018
7. Iran	1 520	1 020	1 020
8. Indonesia	6 360	8	4
9. Hong Kong	120 580	12 796	561
10. Taiwan	157 149	2 254	92
11. Japan	447 441	33 748	9 410
12. Australia	7 373	5 506	166
13. Nigeria	272	0	0
14. South Africa	3 796	3 597	203
15. Venezuela	175	0	0
16. Morocco	176	29	14
TOTALS..............	1 045 328	112 779	40 086

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TABLE 5-15

U.S. 1976 EXPORT/IMPORT COMMODITY TRADE VALUE

SEA TONNES ONLY

Market	Commodity Value		
	Over $5/kg	Over $10/kg	Over $15/kg
1. New York City to Germany	29 995	8 327	2 815
2. Germany to New York City	64 040	16 275	4 378
3. New York City to U.K.	33 278	7 935	3 642
4. United Kingdom to NYC	24 204	3 030	731
5. New York City to Brazil	55 559	5 737	2 800
6. Brazil to New York City	21 047	208	162
7. LAX to Japan	24 916	5 195	3 430
8. Japan to LAS	191 641	43 599	7 252
9. LAX to Indonesia	3 818	959	14
10. Indonesia to LAX	30	3	2
TOTALS...............	448 528	91 268	25 226

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SECTION 6

COMPARATIVE CARGO TRANSPORTATION COSTS
AIR, TRUCK, RAIL, AND WATER

Freighter aircraft presently carry small shipments of high-value, low-density freight over long stage lengths. Airfreight tonne-kilometers as a proportion of total intercity tonne-kilometers have been increasing. If the airfreight portion of total intercity tonne-kilometers is to continue to substantially increase, either the commodities presently carried by air must become relatively more important or airfreight must be used to carry some of the freight presently carried by LTL (less than truckload) trucks, TOFC (trailer on flatcar) trains, and container ships. The competitive cost position of the air mode in transporting this type of freight is considered in this analysis.

Domestic Cost Comparison

The cost of transporting similar high-value, low-density freight over a variety of stage lengths by four different types of transportation is compared. The four different types of transportation are listed below.

Air:	DC-8-63F, volume 298 m^3, design density 177.8 kg/m^3
Truck:	Single 12.2-m LTL trailer via terminals, volume 75.6 m^3 design density 220 kg/m^3
Rail 70:	TOFC, two 12.2-m LTL truck trailers via terminals per freight car, 70-car mixed train
Rail 35:	TOFC, two 12.2-m LTL truck trailers via terminals per freight car, 35-car through train.

Air mode costs exclusive of pickup and delivery were developed from Flying Tiger Line records and should be considered to be accurate 1977 costs. Surface mode costs and air pickup and delivery costs in 1974 dollars were developed from the Appendix to Reference 6-1. These costs were inflated to 1977 levels using References 6-2, 6-3, and 6-4. More accurate surface mode cost information could be developed through the use of city-pair simulation

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models (e.g., Reference 6-5) if sufficient time and resources were to be made available. Considering the very competitive airfreight costs position presented in this analysis, a more accurate and detailed cost comparison should be considered.

Transportation modes are subject to different system and equipment constraints, operational procedures and conditions, and data reporting methods. An understanding of these differences is basic to an objective assessment and comparison of modal costs. A detailed discussion of the pitfalls of making model comparisons is given in Reference 6-6. Consequently, only a few key differences will be considered here.

Line haul cost elements. - Airfreight's principal actual and potential competitors are the LTL truck and similarily loaded truck bodies shipped on TOFC rail cars. LTL truck trailers are loaded at truck terminals much as aircraft are loaded at airfreight terminals. When LTL truck trailers are shipped on TOFC rail cars, they must be transported to and from rail terminals where they are placed on and removed from rail cars. As is illustrated in Figure 6-1, rail line haul is considered to be from truck terminal to truck terminal for mode comparison purposes.

Rail competition. - The rail examples are included in the mode comparison primarily because of their relative cost position and their potential for competition. Few LTL truck trailers are presently piggybacked on either 70-car mixed trains or 35-car through trains. Further, the availability of 35-car through train TOFC service is presently confined primarily to the Chicago, St. Louis corridor.

Density. - Density information differs by mode. Air data are primarily in terms of on-dock and onboard densities and aircraft weight and volume load factors. In this analysis, the density comparison is based on effective densities rather than on-dock or onboard densities partly due to the unavailability of comparable truck and train density information. Effective density is defined to be onboard freight weight exclusive of tare weight divided by available volume. A detailed discussion of effective volume is given in Reference 6-1. Effective densities based on this reference are presented below.

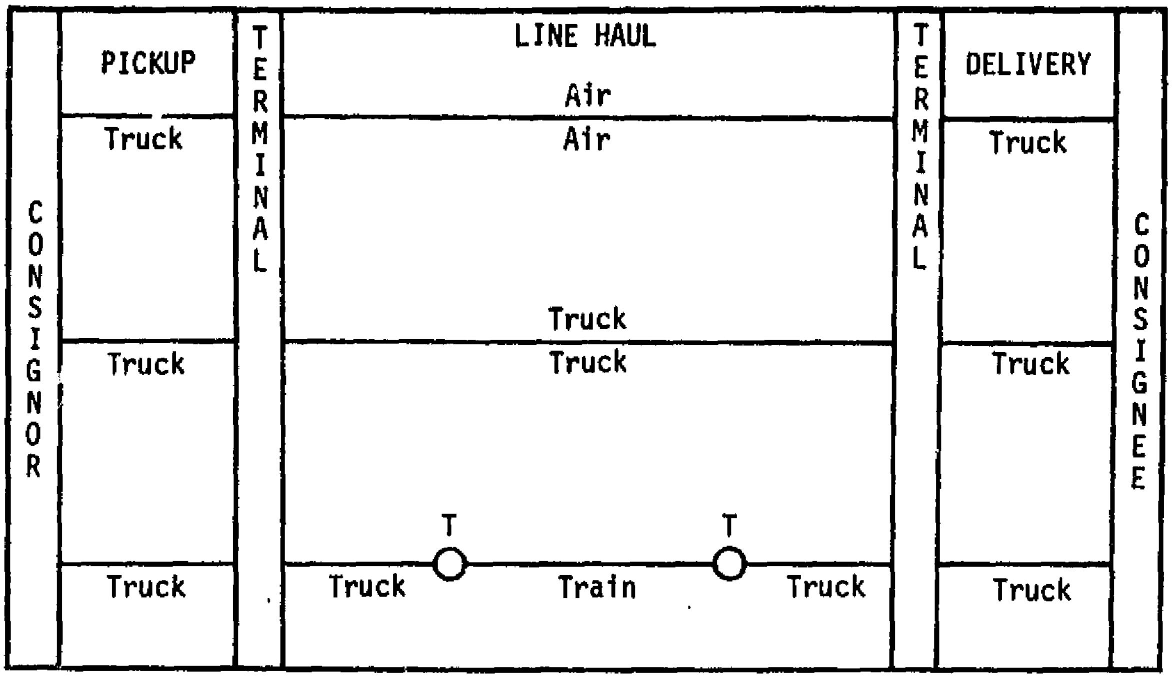

Figure 6-1. Line Haul, Terminal, and Pickup and Delivery Costs

Effective airfreight density - 90.45 kg/m^3
Effective truck freight density - 142.55 kg/m^3
(12.2-m LTL truck via terminals)
Effective rail freight density - 142.55 kg/m^3
(12.2-m LTL truck via terminals)

Any effective density could be used as the basis for comparison between modes without affecting the relative modal costs, providing the chosen effective density is less than the design density for aircraft, 177.8 kg/m^3 for a DC-8-63F. An effective density of 115.69 lb/ft^3 is used as the basis for comparison. This density corresponds to a 65 percent weight factor on a DC-8-63F.

Circuity. - Distance bookkeeping differs by mode. Air data gives credit only for great circle distance while the ground modes are credited with either the traveled distance or the rate-making distance. Both ground mode measures exceed great circle distance with a resulting overstatement of the transportation service provided. Domestic circuity is defined as the ratio of traveled

distance to great circle distance. A detailed discussion of circuity is given in Reference 6-7. Circuity adjustments based on this reference are presented below.

Truck Circuity	- 1.22	1200 kms	- 1000 great circle
Rail Circuity	- 1.425	1425 kms	- 1000 great circle

Level of service. - Air shipments receive a higher level of service than either LTL truck or rail shipments. The air mode affords lower transit times; better on-time performance; less loss, shortage, or damage; and better tracing. No adjustment is made for level of service considerations in this mode comparison.

Total costs. - The comparative total dollar cost of transporting 907 kilograms of freight 1979 kilometers, given measured effective freight densities and no circuity adjustment, is presented in Figure 6-2 and Table 6-1. The cost of air transportation is 2.73 times that of truck, 2.94 times that of a 70-car mixed train and 3.55 times that of a 35-car through TOFC train. These unadjusted comparative total cost ratios are not unexpected.

A similar comparison for a variety of distances given a common effective freight density of 115.7 kg per m^3 and adjusted for circuity is presented in Figure 6-3 and Table 6-2. These adjustments resulted in a reduction in the relative cost of air transportation to 1.82 times that of truck, 2.02 times that of 70-car mixed train, and 2.49 times that of 35-car through TOFC train at the 1979 kilometer distance. These adjusted relative total cost figures indicate a substantially different and somewhat unexpected competitive position for air. A thorough analysis of these adjusted costs follows. The analysis leads to unexpected conclusions concerning the future competitiveness of the air mode.

Line haul, terminal, and pick-up and delivery costs. - A comparison of air and truck line haul costs appears in Table 6-3. (Because of difficulties involved in the allocation of overhead costs, the remainder of the analysis excludes overhead costs. This exclusion does not affect the analysis in any significant manner.) From the data, it can be seen that airline haul costs

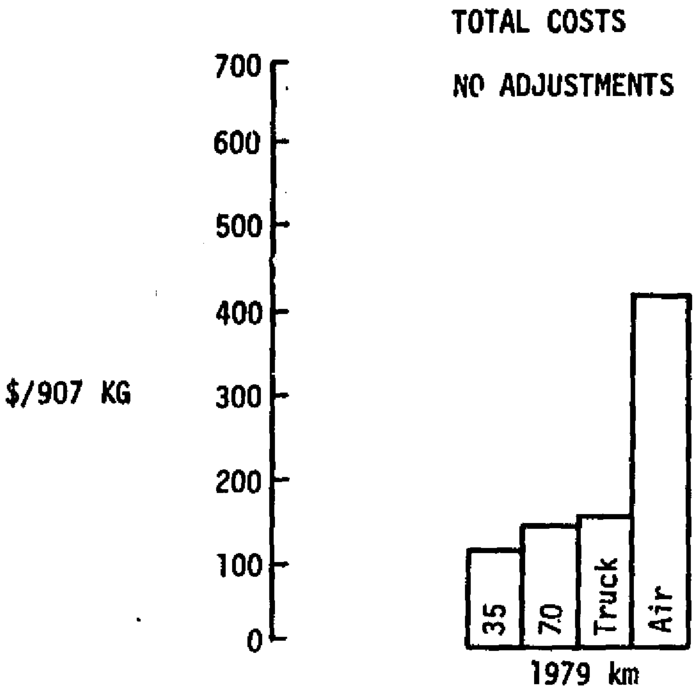

Figure 6-2. Unadjusted Total Costs

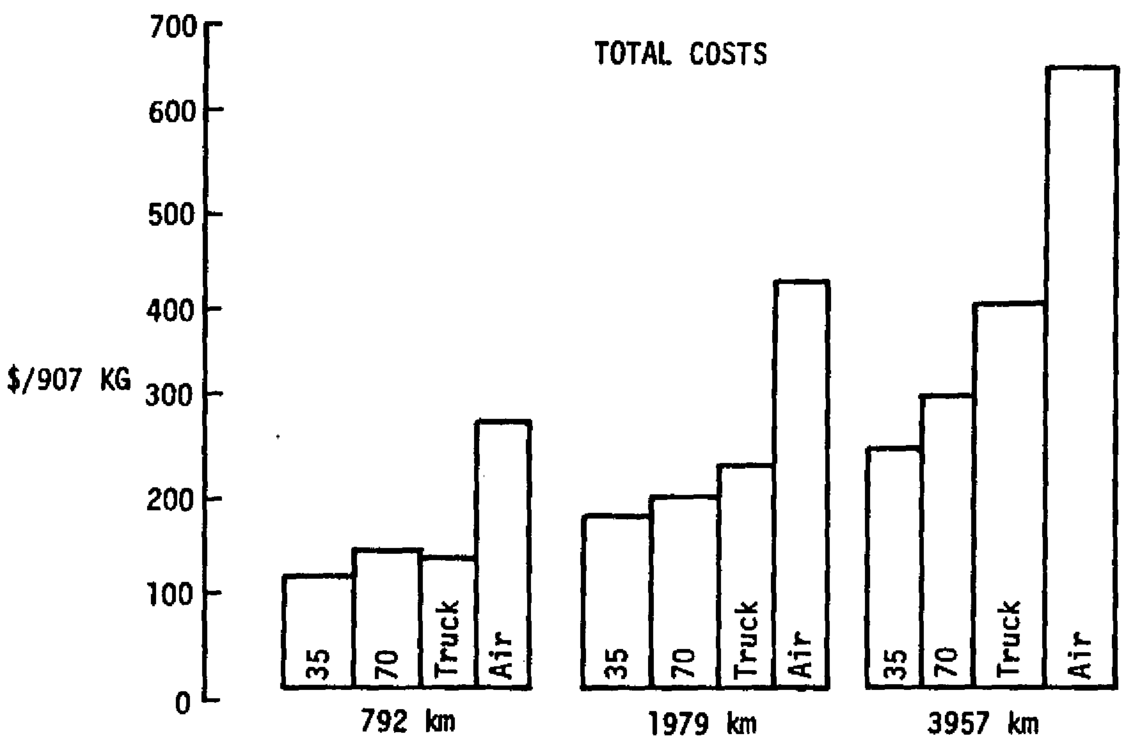

Figure 6-3. Adjusted Total Costs

TABLE 6-1
COMPARATIVE TOTAL COSTS
IN DOLLARS/907 KG
(UNADJUSTED)

MODE	Distance = 1979 kms
Air	$419.45
Truck	$153.87
Air/Truck	$ 2.73
Air	$419.45
Mixed Train	$142.52
Air/Train	$ 2.94
Air	$419.45
Through Train	$118.05
Air/Train	$ 3.55

TABLE 6-2
COMPARATIVE TOTAL COSTS
IN DOLLARS/907 KG
(ADJUSTED FOR DENSITY AND CIRCUITY)

	Distance in Kilometers				
Mode	792	1328	1979	2638	3957
Air	275.32	344.43	419.45	499.34	659.49
Truck	128.38	173.92	230.80	287.80	401.52
Air/Truck	2.14	1.98	1.82	1.74	1.64
Air	275.32	344.43	419.45	499.34	659.49
Mixed Train	148.52	170.01	207.15	233.97	297.79
Air/Train	1.85	2.03	2.02	2.13	2.21
Air	275.32	344.43	419.45	499.34	659.49
Through Train	118.85	140.83	168.27	195.29	250.47
Air/Train	2.32	2.45	2.49	2.56	2.63

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TABLE 6-3

AIR AND TRUCK LINE HAUL COSTS IN DOLLARS/907 KG

	Distance	Line Haul Total	Line Haul Fuel	Line Haul Labor	Line Haul Capital	Line Haul Maintenance
Air	792	103.69	28.64	19.41	42.19	13.45
Truck	792	63.98	5.36	38.98	12.66	7.07
Air/Truck	792	1.62	5.34	0.50	3.33	1.90
Air	1328	163.24	46.07	31.21	64.32	21.63
Truck	1328	106.66	8.95	64.81	21.10	11.80
Air/Truck	1328	1.53	5.15	0.48	3.05	1.83
Air	1979	226.76	62.77	42.53	91.97	29.49
Truck	1979	159.97	13.40	97.23	31.65	17.69
Air/Truck	1979	1.42	4.68	0.44	2.91	1.67
Air	2638	294.98	81.69	55.35	119.56	38.39
Truck	2638	213.28	17.87	129.62	42.20	23.59
Air/Truck	2638	1.38	4.57	0.43	2.83	1.63
Air	3957	431.73	119.61	81.05	174.87	56.20
Truck	3957	319.96	26.82	194.45	63.30	35.39
Air/Truck	3957	1.35	4.46	0.42	2.76	1.59

are 1.42 times truck line haul costs at the 1979 kilometer distance. The labor and fuel components of this comparison deserve special attention. Air labor costs are less than half truck labor costs at all distances, while air fuel costs are 4.68 times truck fuel costs at the 1979 kilometer distance. The fuel cost findings are consistent with those developed in Reference 6-6 given relative fuel price inflation rates. Other published fuel cost comparisons place the airplane in a less-competitive position: However, these analyses failed to make density and circuity adjustments. A listing of other published fuel cost comparisons can be found in Reference 6-6.

A comparison of air and rail line haul costs appears in Tables 6-4 and 6-5. Rail line haul costs range from 41 to 79 percent of airline haul costs. The maintenance and fuel components of this comparison deserve special attention. The rail mode is burdened with high maintenance costs. The indicated comparative rail fuel costs are higher than those indicated in other studies. The high rail fuel costs can be explained by density and circuity adjustments and the inclusion of truck movements between truck and rail terminals in rail line haul costs.

Air and truck terminal costs are presented in Tables 6-6 and 6-7 respectively. (In Table 6-6, actual shipment size is 1814 kilograms. Costs given are one-half of 1814 kilogram shipment costs. In Table 6-7, costs also apply to truck mode.) These costs are compared in Table 6-8, which also applies to rail mode. The comparison indicates air terminal costs are surprisingly high when compared to truck terminal costs.

Air terminal capital costs are 4.98 times truck terminal capital costs, and this can be partially explained by high airport land values and relatively more-mechanized air terminals. However, the major component for both modes of cost is labor not capital. The extreme air terminal labor cost must be explained in terms of air terminal peaking, aircraft weight and balance considerations, the contoured shape of air containers, the level of service provided by the air mode, and inefficiency.

Comparative air and truck pickup and delivery costs presented in Table 6-9 also apply to rail mode. The comparative capital cost component of the

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TABLE 6-4

AIR AND RAIL LINE HAUL COSTS IN DOLLARS/907 KG

RAIL - 70-CAR MIXED TRAIN

	Distance km	Line Haul	Fuel	Labor	Capital	Maintenance
Air	792	103.69	28.64	19.41	42.19	13.45
Rail	792	82.04	9.17	19.80	35.73	17.34
Air/Rail	792	1.26	3.12	0.98	1.18	0.78
Air	1328	163.24	46.07	31.21	64.32	21.63
Rail	1328	101.98	12.32	23.18	42.78	23.70
Air/Rail	1328	1.60	3.74	1.35	1.50	.91
Air	1979	226.76	62.77	42.53	91.97	29.49
Rail	1979	136.44	17.76	28.99	54.97	34.72
Air/Rail	1979	1.66	3.53	1.47	1.67	0.85
Air	2638	294.98	81.69	55.35	119.56	38.39
Rail	2638	161.34	21.70	33.19	63.77	42.68
Air/Rail	2638	1.83	3.76	1.67	1.87	0.90
Air	3957	431.73	119.61	81.05	174.87	56.20
Rail	3957	220.56	31.06	43.20	84.71	61.59
Air/Rail	3957	1.96	3.85	1.88	2.06	0.91

Table 6-5

AIR AND RAIL LINE HAUL COSTS IN DOLLARS/907 KG

RAIL 35-CAR THROUGH TRAIN

	Distance, kms	Line Haul	Fuel	Labor	Capital	Maintenance
Air	792	103.69	28.64	19.41	42.19	13.45
Rail	792	54.50	6.50	19.19	15.65	13.16
Air/Rail	792	1.90	4.41	1.01	2.70	1.02
Air	1328	163.24	46.07	31.21	64.32	21.63
Rail	1328	74.88	9.98	23.93	20.03	20.94
Air/Rail	1328	2.18	4.62	1.30	3.21	1.03
Air	1979	226.76	62.77	42.53	91.97	29.49
Rail	1979	100.33	14.34	29.84	25.50	30.65
Air/Rail	1979	2.26	4.38	1.43	3.61	0.96
Air	2638	294.98	81.69	55.35	119.56	38.39
Rail	38	125.72	18.69	35.73	30.96	40.34
Air/Rail	2638	2.35	4.37	1.55	3.86	0.95
Air	3957	431.73	119.61	81.05	174.87	56.20
Rail	3957	175.56	27.39	47.53	41.89	59.75
Air/Rail	3957	2.46	4.37	1.71	4.17	0.94

TABLE 6-6

AIR TERMINAL COSTS

Type of Shipment	Bulk	Bulk	Bulk	Bulk	Bulk	Container Shipments		
Weight in Kg	907	907	907	907	907	907	907	907
No. of Pieces or Container Type	1	5	10	20	42	1	3.48	.5
Kg per Piece of Container Type	907	181	91	45	21.6	FTC	D-575	A
O & D Costs (dollars)	73.39	76.66	80.74	88.92	106.90	72.57	88.64	64.04
Labor (dollars)	66.58	69.85	73.93	82.11	100.09	65.76	81.83	57.23
Capital (dollars)	6.81	6.81	6.81	6.81	6.81	6.81	6.81	6.81
Transload Costs Labor (dollars)	36.76	38.62	40.94	45.59	55.80	37.45	43.67	31.64

TABLE 6-7

TRUCK TERMINAL COSTS

Type of Shipment	Bulk
Weight in Kilograms	907
No. of Pieces	20 (Estimate)
Kg per Piece	45 (Estimate)
O & D Costs	$27.42
Labor	$26.02
Capital	$ 1.40

TABLE 6-8

AIR AND TRUCK TERMINAL COSTS IN DOLLARS/907 KG

	O & D Costs	Labor	Capital
Air	$88.92	$82.11	$6.81
Truck	$27.42	$26.02	$1.40
Air/Truck	3.24	3.16	4.86

data indicates an inconsistency in the data. This inconsistency was most likely caused by differences in accounting procedures. If the overall pickup and delivery cost comparison is accepted, then airfreight suffers a substantial pickup and delivery cost penalty caused by the thinness of airfreight markets.

TABLE 6-9

PICKUP AND DELIVERY COSTS IN DOLLARS/907 KG

Air	50.96	Truck	27.57	Air/Truck	1.85
Fuel	5.52	Fuel	5.33	Fuel	1.04
Labor	23.91	Labor	16.76	Labor	1.43
Capital	13.78	Capital	0.79	Capital	17.44
Maintenance	7.75	Maintenance	4.69		1.65

Line haul, terminal, and pickup and delivery costs are summarized in Figure 6-4 and Table 6-10. Corresponding percentage comparisons are presented in Figure 6-5 and Table 6-11. The percentage figures indicate line haul costs are a smaller percent of total costs for the air mode than other modes: A result that was not expected at the beginning of this study. Another unexpected finding concerns terminal costs. Terminal costs are a larger portion of total costs for the air mode than other modes. As expected, pickup and delivery costs are relatively more significant for rail than other modes.

Fuel, labor, capital and maintenance costs. - Modal fuel, labor, capital, and maintenance costs are presented in Figure 6-6 and Tables 6-12 through 6-15, and Figure 6-7 and Table 6-16. The data indicate that the air mode is fuel and capital inefficient relative to the other modes providing level of service considerations are ignored, an expected conclusion attributable to the nature of the line haul vehicles. Even though airline haul labor expenses are less than half truck line haul labor expenses for all shipment distances, air labor expenses are greater than truck labor expenses for shipments of less than approximately 1600 kilometers due to extreme air terminal labor costs. On longer trips, low airline haul costs outweigh high air terminal labor costs. Airline haul costs are similar to rail line haul labor costs on short trips, a conclusion that is obscured once terminal labor costs are included.

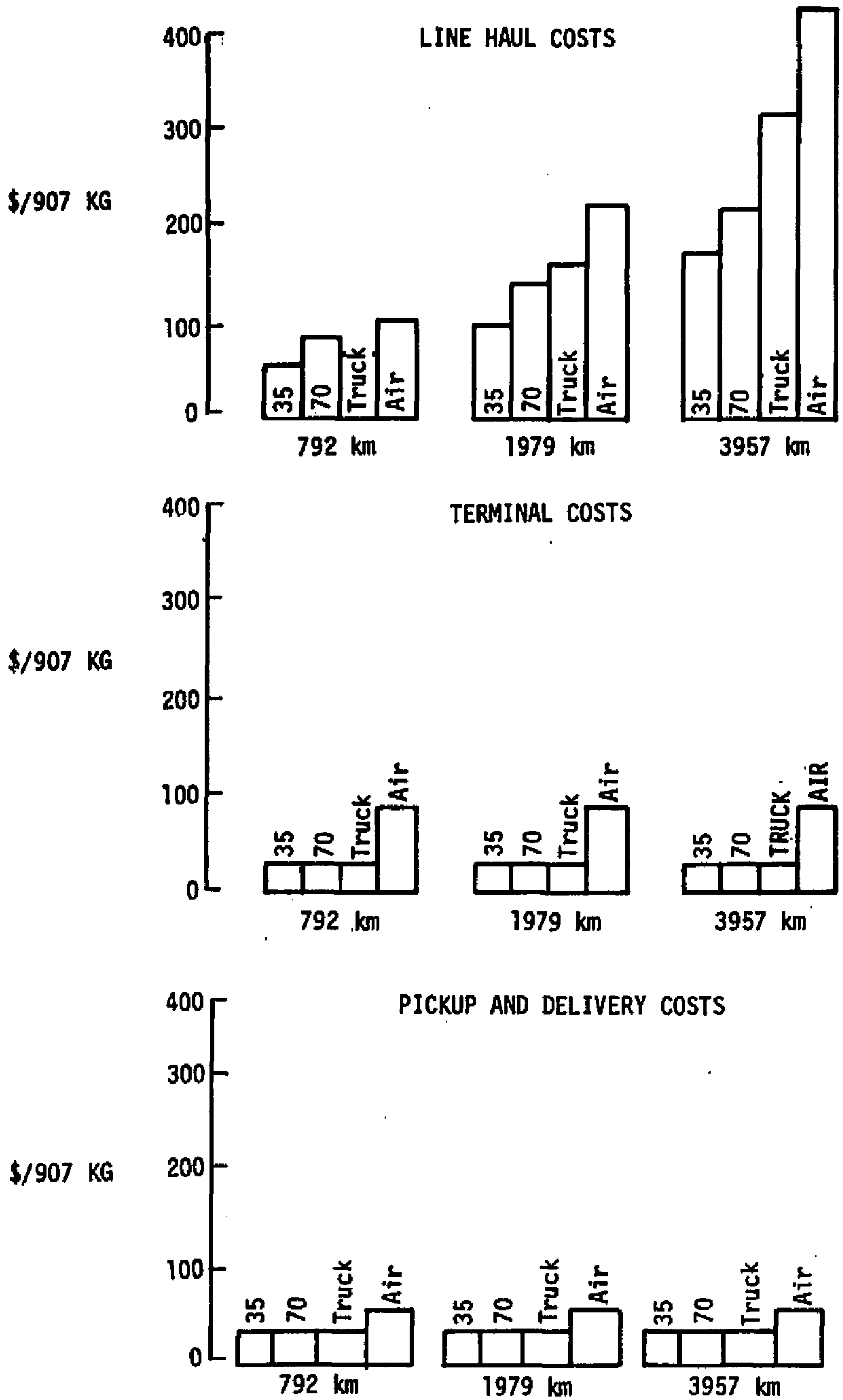

Figure 6-4. Line Haul, Terminal, and Pickup and Delivery Costs

TABLE 6-10

LINE HAUL, TERMINAL, AND PICK UP AND DELIVERY COSTS IN DOLLARS/907 KG

	Distance in Kilometers				
	792	1230	1979	2638	3957
Line Haul					
Air	103.69	163.24	226.76	294.98	431.73
Truck	63.98	106.66	159.97	213.28	319.96
Mixed Train	82.04	101.98	136.44	161.34	220.56
Through Train	54.50	74.88	100.33	125.72	175.56
Terminal					
Air	88.92	88.92	88.92	88.92	88.92
Truck, Mixed Train, Thru Train	27.42	27.42	27.42	27.42	27.42
Pick-Up & Delivery					
Air	50.96	50.96	50.96	50.96	50.96
Truck, Mixed Train, Through Train	27.57	27.57	27.57	27.57	27.57
Air					
Line Haul	103.69	163.24	226.76	294.98	431.73
Terminal	88.92	88.92	88.92	88.92	88.92
PU&D	50.96	50.96	50.96	50.96	50.96
Truck					
Line Haul	63.98	106.66	159.97	213.28	319.96
Terminal	27.42	27.42	27.42	27.47	27.42
PU&D	27.57	27.57	27.57	27.57	27.57
70 Car Mixed Train					
Line Haul	82.04	101.98	136.44	161.34	220.56
Terminal	27.42	27.42	27.42	27.42	27.42
PU&D	27.57	27.57	27.57	27.57	27.57
35 Car Thru Train					
Line Haul	54.50	74.88	100.33	125.72	175.56
Terminal	27.42	27.42	27.42	27.42	27.42
PU&D	27.57	27.57	27.57	27.57	27.57

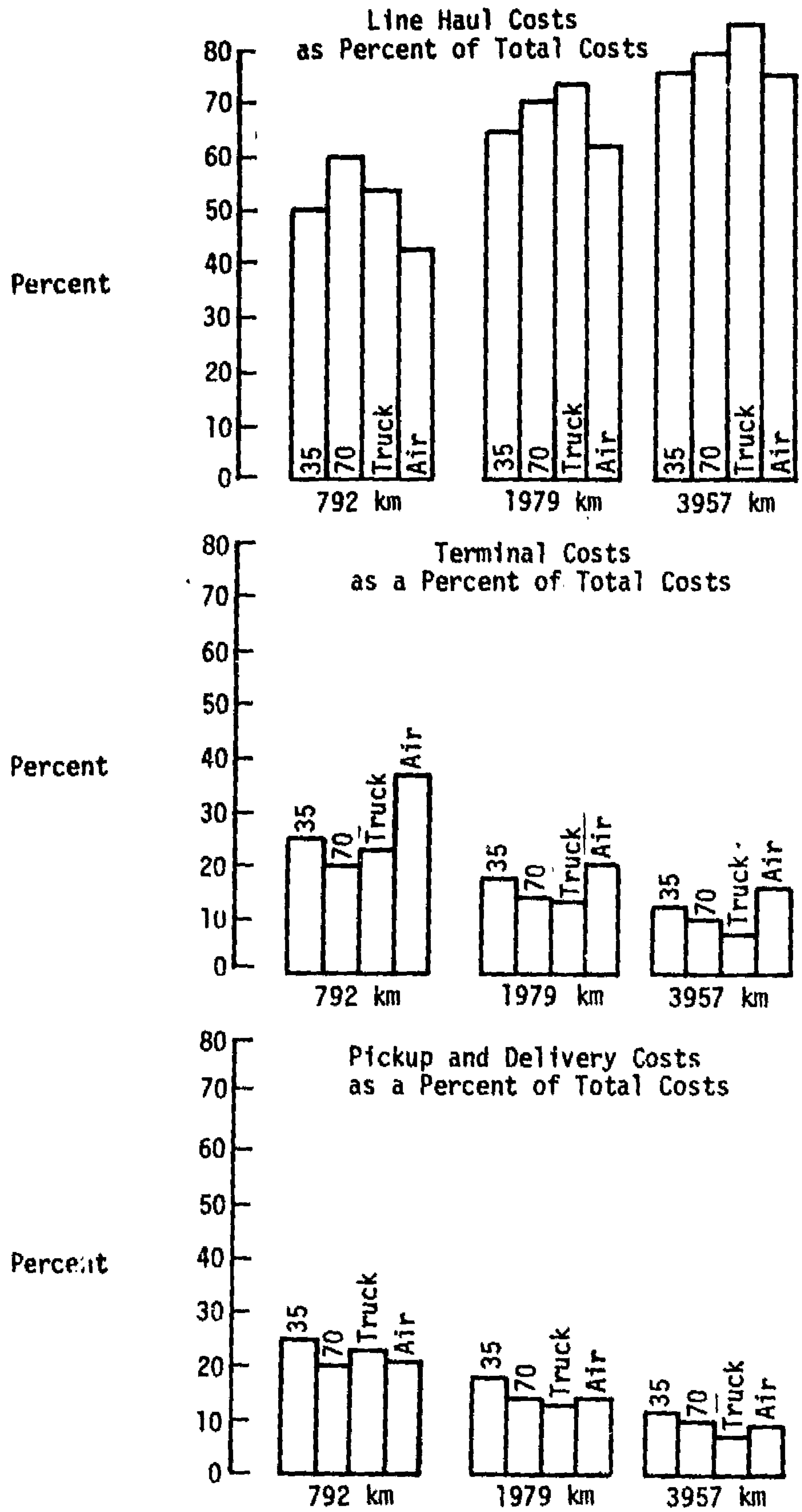

Figure 6-5. Percentage of Total Costs

TABLE 6-11

LINE HAUL, TERMINAL, AND PICKUP AND DELIVERY COSTS AS A PERCENT OF TOTAL COSTS

	Distance in Kilometers				
	792	1320	1979	2638	3957
Line Haul					
Air	43	54	62	68	76
Truck	54	66	74	80	85
Mixed Train	60	65	71	75	80
Through Train	50	58	65	70	76
Terminal					
Air	37	29	24	20	16
Truck	23	17	13	10	7
Mixed Train	20	17	14	13	10
Through Train	25	21	18	15	12
PU&D					
Air	21	17	14	12	9
Truck	23	17	13	10	7
Mixed Train	20	18	14	13	10
Through Train	25	21	18	15	12
Air					
Line Haul	43	54	62	68	76
Terminal	37	29	24	20	16
PU&D	21	17	14	12	9
Truck					
Line Haul	54	66	74	80	85
Terminal	23	17	13	10	7
PU&D	23	17	13	10	7
70-Car Mixed Train					
Line Haul	60	65	71	75	80
Terminal	20	17	14	13	10
PU&D	20	18	14	13	10
35-Car Through Train					
Line Haul	50	58	65	70	76
Terminal	25	21	18	15	12
PU&D	25	21	18	15	12

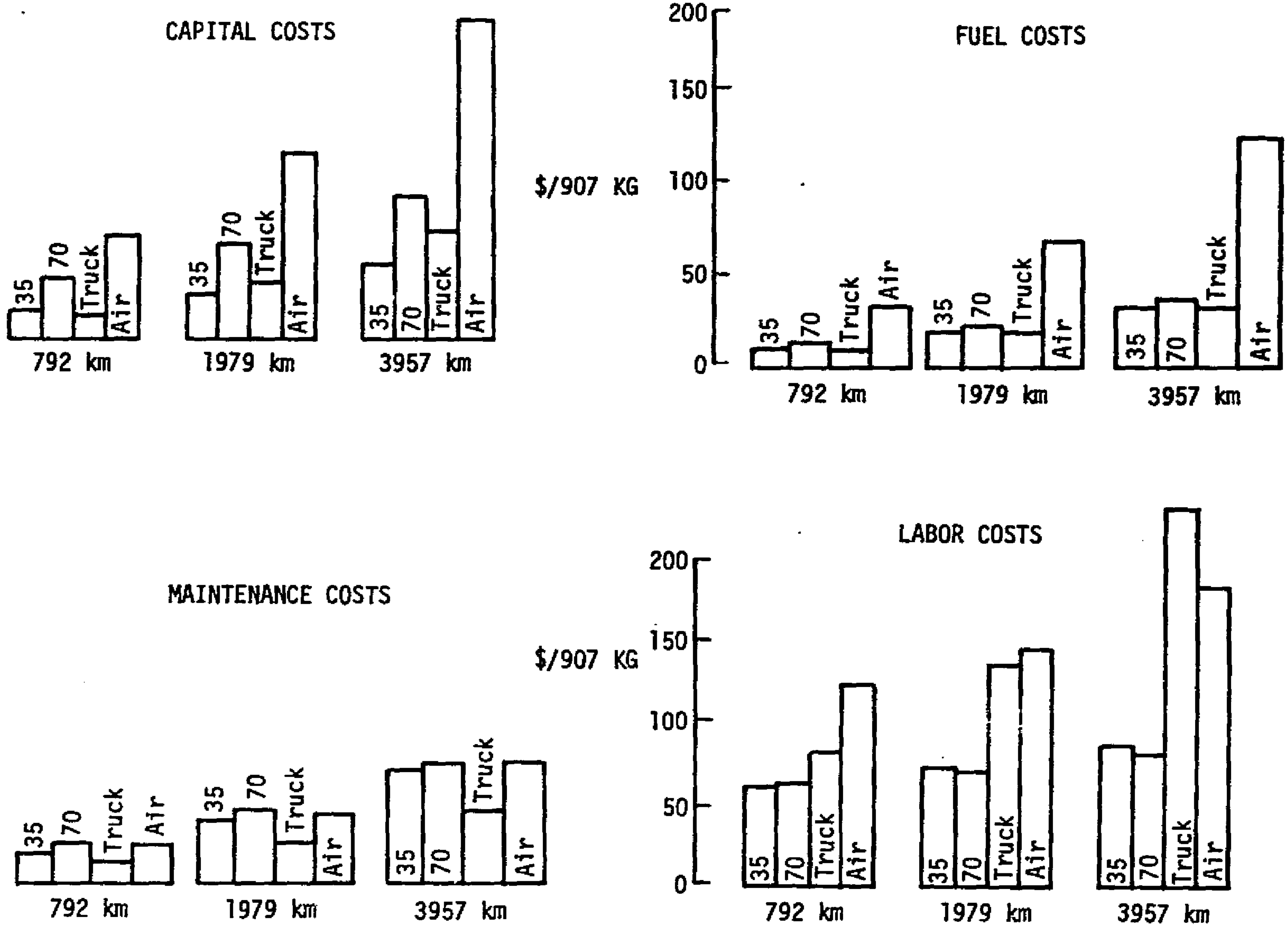

Figure 6-6. Modal Fuel, Labor, Capital, and Maintenance Costs

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TABLE 6-12

AIR FUEL, LABOR, CAPITAL, AND MAINTENANCE COSTS IN DOLLARS/907 KG

	Distance in Kilometers				
	792	1320	1979	2638	3957
Fuel					
Line Haul	28.64	46.07	62.77	81.69	119.61
PU&D	5.52	5.52	5.52	5.52	5.52
	34.16	51.59	68.29	87.21	125.13
Labor					
Line Haul	19.41	31.21	42.53	55.35	81.05
Terminal	82.11	82.11	82.11	82.11	82.11
PU&D	23.91	23.91	23.91	23.91	23.91
	125.43	137.23	148.55	161.37	187.07
Capital					
Line Haul	42.19	64.32	91.97	119.56	174.87
Terminal	6.81	6.81	6.81	6.81	6.81
PU&D	13.78	13.78	13.78	13.78	13.78
	62.78	84.91	112.56	140.15	195.46
Maintenance					
Line Haul	13.45	21.63	29.49	38.39	56.20
PU&D	7.75	7.75	7.75	7.75	7.75
	21.20	29.38	37.24	46.14	63.95
Fuel					
Line Haul	28.64	46.07	62.77	81.69	119.61
PU&D	5.52	5.52	5.52	5.52	5.52
	34.16	51.59	68.29	87.21	125.13
Labor					
Line Haul	19.41	31.21	42.53	55.35	81.05
Terminal	82.11	82.11	82.11	82.11	82.11
PU&D	23.11	23.11	23.11	23.11	23.11
	125.42	137.23	.48.55	161.37	187.07
Capital					
Line Haul	42.19	64.32	91.97	119.56	174.87
Terminal	6.81	6.81	6.81	6.81	6.81
PU&D	13.78	13.78	13.78	13.78	13.78
	62.78	84.91	112.56	140.15	195.46
Maintenance					
Line Haul	13.45	21.63	29.47	38.39	56.20
PU&D	7.75	7.75	7.75	7.75	7.75
	21.20	29.30	37.24	46.14	63.95

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TABLE 6-13

TRUCK FUEL, LABOR, CAPITAL, AND MAINTENANCE COSTS IN DOLLARS/907 KG

	Distance in Kilometers				
	792	1320	1978	2638	3957
Fuel					
Line Haul	5.36	8.95	13.40	17.87	26.82
PU&D	5.33	5.33	5.33	5.33	5.33
	10.69	14.28	18.73	23.20	32.15
Labor					
Line Haul	38.89	64.81	97.23	129.62	194.45
Terminal	26.02	26.02	26.02	26.02	26.02
PU&D	16.76	16.76	16.76	16.76	16.76
	81.67	107.59	140.01	172.40	237.23
Capital					
Line Haul	12.66	21.10	31.65	42.20	63.30
Terminal	1.40	1.40	1.40	1.40	1.40
PU&D	.79	.79	.79	.79	..79
	14.85	23.29	33.84	44.39	65.49
Maintenance					
Line Haul	7.07	11.80	17.69	23.59	35.39
PU&D	4.69	4.69	4.69	4.69	4.69
	11.76	16.49	22.38	28.28	40.08

TABLE 6-14
70-CAR MIXED TRAIN FUEL, LABOR, CAPITAL
AND MAINTENANCE COSTS IN DOLLARS/907 KG

	Distance in Kilometers				
	792	1320	1979	2638	3957
Fuel					
Line Haul	9.17	12.32	17.76	21.70	31.06
PU&D	5.33	5.33	5.33	5.33	5.33
	14.50	17.65	23.09	27.03	36.39
Labor					
Line Haul	19.80	23.18	28.99	33.19	43.20
Terminal	26.02	26.02	26.02	26.02	26.02
PU&D	16.76	16.76	16.76	16.76	16.76
	62.58	65.96	71.77	75.97	85.98
Capital					
Line Haul	35.73	42.78	54.97	63.77	84.71
Terminal	1.40	1.40	1.40	1.40	1.40
PU&D	.79	.79	.79	.79	.79
	37.92	44.97	57.16	65.96	86.90
Maintenance					
Line Haul	17.34	23.70	34.72	42.68	61.59
PU&D	4.69	4.69	4.69	4.69	4.69
	22.03	28.39	39.41	47.37	66.28

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TABLE 6-15
35-CAR THROUGH TOFC TRAIN FUEL, LABOR, CAPITAL AND MAINTENANCE COSTS IN DOLLARS/907 KG

	Distance in Kilometers				
	792	1320	1979	2638	3957
Fuel					
Line Haul	6.50	9.98	14.34	18.69	27.39
PU&D	5.33	5.33	5.33	5.33	5.33
	11.83	15.31	19.67	24.02	32.72
Labor					
Line Haul	19.19	23.93	29.84	35.73	47.53
Terminal	26.02	26.02	26.02	26.02	26.02
PU&D	16.76	16.76	16.76	16.76	16.76
	61.97	66.71	72.62	78.51	90.31
Capital					
Line Haul	15.65	20.03	25.50	30.96	41.89
Terminal	1.40	1.40	1.40	1.40	1.40
PU&D	0.79	0.79	0.79	0.79	0.79
	17.84	22.22	27.69	33.15	44.08
Maintenance					
Line Haul	13.16	20.94	30.65	40.34	59.75
PU&D	4.69	4.69	4.69	4.69	4.69
	17.85	25.63	35.34	45.03	64.44

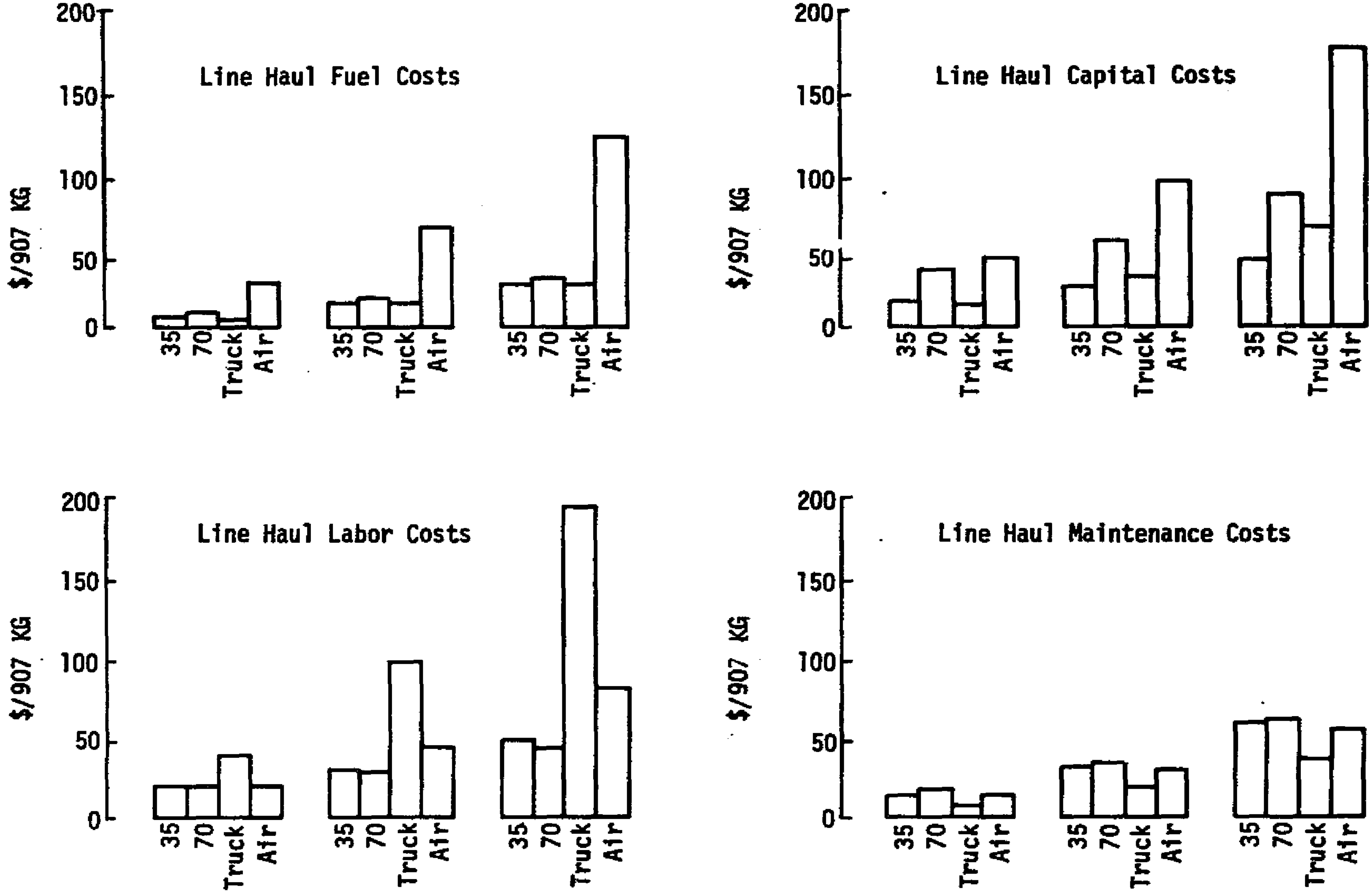

Figure 6-7. Line Haul Costs

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TABLE 6-16

FUEL, LABOR, CAPITAL, AND MAINTENANCE COSTS BY MODE IN DOLI ,RS/907 KG

	Distance in Kilometers				
	792	1320	1979	2638	3957
Fuel					
Air	34.16	51.59	68.29	87.21	125.13
Truck	10.69	14.28	18.73	23.20	32.15
Mixed Train	14.50	17.65	23.09	27.03	36.39
Through Train	11.83	15.31	19.67	24.02	32.72
Labor					
Air	125.42	137.23	148.55	161.37	187.07
Truck	81.67	107.59	140.01	172.40	237.23
Mixed Train	62.58	65.96	71.77	75.97	85.98
Through Train	61.97	66.71	72.62	78.51	90.31
Capital					
Air	62.78	84.91	112.56	140.15	195.46
Truck,	14.85	23.29	33.84	44.39	65.49
Mixed Train	37.92	44.97	57.16	65.96	86.90
Through Train	17.84	22.22	27.69	33.15	44.08
Maintenance					
Air	21.20	29.38	37.24	46.14	63.95
Truck	11.76	16.49	22.38	28.28	40.08
Mixed Train	22.03	28.39	39.41	47.37	66.28
Through Train	17.85	25.63	35.34	45.03	64.44
Air					
Fuel	34.16	51.59	68.29	87.21	125.13
Labor	125.42	137.23	148.55	161.37	187.07
Capital	62.78	84.91	112.56	140.15	195.46
Maintenance	21.20	29.38	37.24	46.14	63.95
Truck					
Fuel	10.69	14.28	18.73	23.20	32.15
Labor	81.67	107.59	140.01	172.40	237.23
Capital	14.85	23.29	33.84	44.39	65.49
Maintenance	11.76	16.49	22.38	28.28	40.08
70-Car Mixed Train					
Fuel	11.83	15.31	19.67	24.02	36.39
Labor	61.97	66.71	72.62	78.51	85.98
Capital	17.84	22.22	27.69	33.15	86.90
Maintenance	17.85	25.63	35.34	45.03	66.28
35-Car Through Train					
Fuel	14.50	17.65	23.09	27.03	32.72
Labor	62.58	65.96	71.99	75.97	90.31
Capital	37.92	44.97	57.16	65.96	44.08
Maintenance	22.03	28.39	39.41	47.37	64.44

Ignoring level of service considerations, the air mode is labor inefficient when compared to the rail mode for long trips. The maintenance cost comparison leads to another unexpected conclusion: Even though the air maintenance costs exceed truck maintenance costs, air maintenance costs compare favorably to rail maintenance.

Percentage fuel, labor, capital, and maintenance costs comparisons are presented in Figure 6-8 and Tables 6-17 through 6-21, in which totals are rounded to the nearest percentages. The air mode is the most fuel intensive of the various modes. However, the train is surprisingly fuel intensive compared to the airplane, especially for short distance freight movements. As expected, the airplane is more capital intensive than the other modes.

The truck and 35-car through train forms of transportation are more labor intensive than the air mode. The truck mode is especially labor intensive. Over 60 percent of truck line haul costs are labor versus less than 20 percent for air. The rail forms of transportation are very maintenance intensive; this in indicative of American rail freight problems. Air and truck mode maintenance costs are approximately one-tenth of total costs versus 16 to 28 percent of total costs for the rail mode.

Inflation. - Approximate cost increases for the 3 year period 1974 to 1977 are presented in Tables 6-22 and 6-23. These cost increases are based on References 6-2, 6-3, 6-4, and 6-8. Air mode costs have increased 2 to 4 percent more than other mode costs over the 3 year period due to large air mode fuel and labor cost increases. Air mode capital cost increases have been less severe than those experienced by the other modes.

Domestic cost comparison conclusions. - Air costs are substantially greater than truck or rail costs. Terminal and pickup and delivery costs were found to be more responsible for this conclusion than expected. If efficiency improvement and technological change could lower air terminal and pickup and delivery costs to the point where they equaled truck terminal and pickup and delivery costs, then the difference in cost between planes and trucks would be comparable to the difference between trucks and trains. This surprising conclusion is presented in Figure 6-9 and Table 6-24.

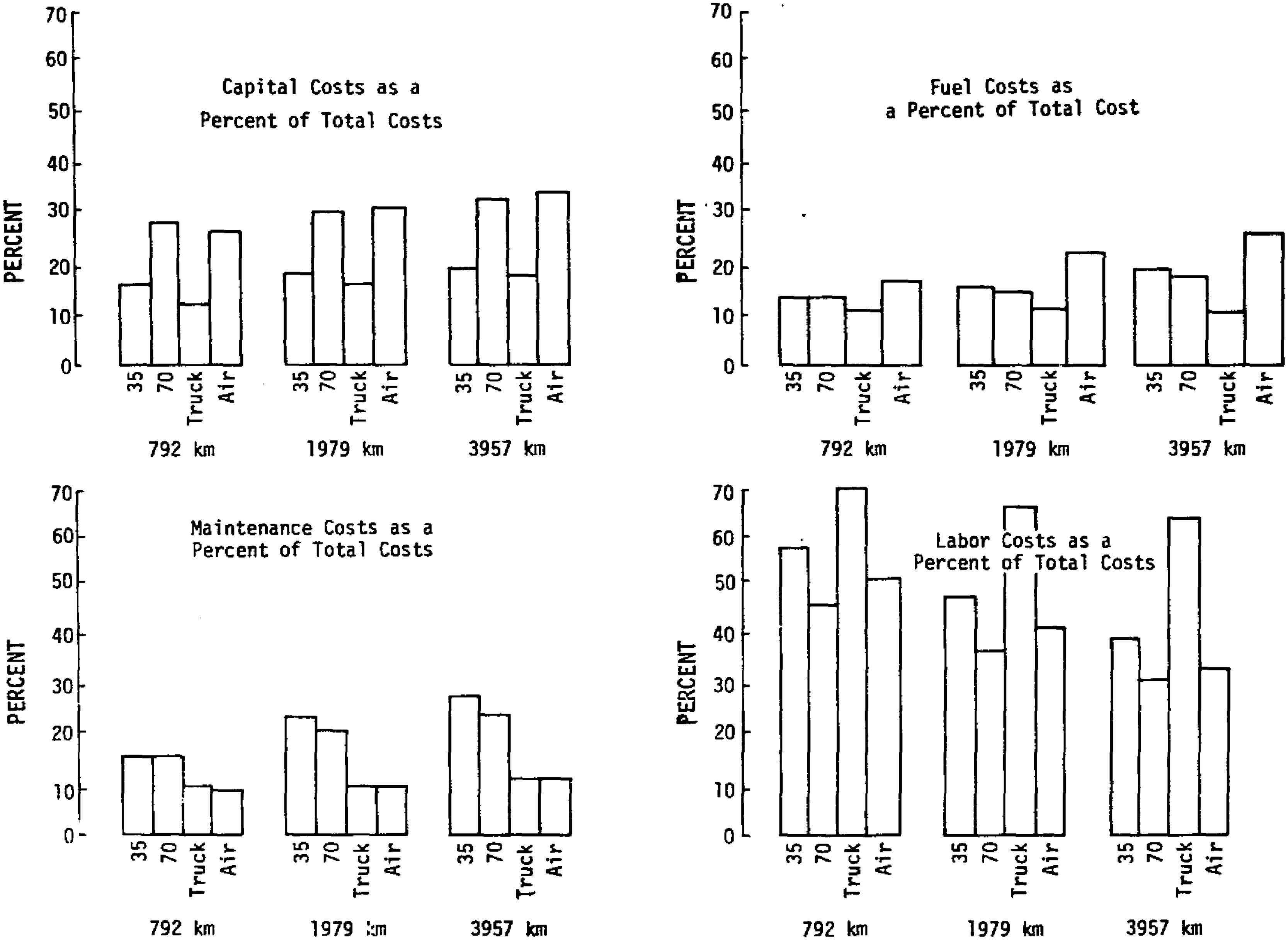

Figure 6-8. Percentages of Total Costs

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TABLE 6-17

PERCENTAGE AIR COSTS BY INPUT

	Distance in Kilometers				
	792	1320	1979	2638	3957
Fuel					
Line Haul	12	15	17	19	21
PU&D	2	2	2	1	1
	14	17	19	20	22
Labor					
Line Haul	8	10	12	13	14
Terminal	34	27	22	19	14
PU&D	10	8	7	5	4
	51	45	41	37	33
Capital					
Line Haul	17	21	25	27	31
Terminal	3	2	2	2	1
PU&D	6	5	4	3	2
	26	28	31	32	34
Maintenance					
Line Haul	6	7	8	9	10
PU&D	3	3	2	2	1
	9	10	10	11	11

TABLE 6-18

PERCENTAGE TRUCK COSTS BY INPUT

	Distance in Kilometers				
	792	1320	1979	2638	3975
Fuel					
Line Haul	5	6	6	7	7
PU&D	4	3	2	2	1
	9	9	9	9	9
Labor					
Line Haul	33	40	45	48	52
Terminal	22	16	12	10	7
PU&D	14	10	8	6	4
	69	67	65	64	63
Capital					
Line Haul	11	13	15	16	17
Terminal	1	1	1	1	0
PU&D	1	0	0	0	0
	12	14	16	17	17
Maintenance					
Line Haul	6	7	8	9	9
PU&D	4	3	2	2	1
	10	10	10	11	11

TABLE 6-19

70-CAR MIXED TRAIN PERCENTAGE COSTS BY INPUT

	Distance in Kilometers				
	792	1320	1979	2638	3957
Fuel					
Line Haul	7	8	9	10	11
PU&D	4	3	3	2	3
	11	11	12	12	13
Labor					
Line Haul	14	15	15	15	16
Terminal	19	17	14	12	9
PU&D	12	11	9	8	6
	46	42	37	35	31
Capital					
Line Haul	26	27	29	29	31
Terminal	1	1	1	1	1
PU&D	1	1	0	0	0
	28	29	30	30	32
Maintenance					
Line Haul	13	15	18	20	22
PU&D	3	3	2	2	2
	16	18	21	22	24

TABLE 6-20

35-CAR THROUGH TRAIN PERCENTAGE COSTS BY INPUT

	Distance in Kilometers				
	792	1320	1979	2638	3957
Fuel					
Line Haul	6	8	9	10	12
PU&D	5	4	3	3	2
	11	12	13	13	14
Labor					
Line Haul	18	18	19	20	21
Terminal	24	20	17	14	11
PU&D	15	13	11	9	7
	57	51	47	44	39
Capital					
Line Haul	14	15	16	17	18
Terminal	1	1	1	1	1
PU&D	1	1	1	0	0
	16	17	18	18	19
Maintenance					
Line Haul	12	16	20	22	26
PU&D	4	4	3	3	2
	16	20	23	25	28

TABLE 6-21

PERCENTAGE COSTS BY INPUT

	Distance in Kilometers				
	792	1320	1979	2638	3957
Fuel					
Air	14	17	19	20	22
Truck	9	9	9	9	9
Mixed Train	11	11	12	12	12
Through Train	11	12	13	13	14
Labor					
Air	51	45	41	37	33
Truck	69	67	65	64	63
Mixed Train	46	42	37	35	31
Through Train	57	51	47	44	39
Capital					
Air	26	28	31	32	34
Truck	12	14	16	17	17
Mixed Train	28	29	30	30	32
Through Train	16	17	18	18	19
Maintenance					
Air	9	10	10	11	11
Truck	10	10	10	11	11
Mixed Train	16	18	21	22	24
Through Train	16	20	23	25	28
Air					
Fuel	14	17	19	20	22
Labor	51	45	41	37	33
Capital	26	28	31	32	34
Maintenance	9	10	10	11	11
Truck					
Fuel	9	9	9	9	9
Labor	69	67	65	64	63
Capital	12	14	16	17	17
Maintenance	10	10	10	11	11
70-Car Mixed Train					
Fuel	11	11	12	12	12
Labor	46	42	37	35	31
Capitol	28	29	30	30	32
Maintenance	16	18	21	22	24
35-Car Through Train					
Fuel	11	12	13	13	14
Labor	57	51	47	44	39
Capital	16	17	18	18	19
Maintenance	16	20	23	25	28

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TABLE 6-22

PERCENTAGE COST INCREASES, 1974-1977

	Air	Truck	70-Car Mixed Train	35-Car Thru Train
Line Haul	33	29	28	28
Fuel	58	28	42	42
Labor	34	32	30	30
Capital	23	25	27	27
Maintenance	23	23	23	23
Terminal	33	32	32	32
Labor	34	32	32	32
Capital	27	27	27	27
PU&D	29	32	32	32
Fuel	40	40	40	40
Labor	32	32	32	32
Capital	25	25	25	25
Maintenance	23	23	23	23

TABLE 6-23

PERCENTAGE COST INCREASES, 1974-1977

	Distance in Kilometers				
	792	1320	1979	2638	3957
Mode					
Air	32	32	32	33	33
Truck	30	30	30	30	29
70-Car Mixed Train	30	29	29	29	29
35-Car Through Train	30	30	29	29	29

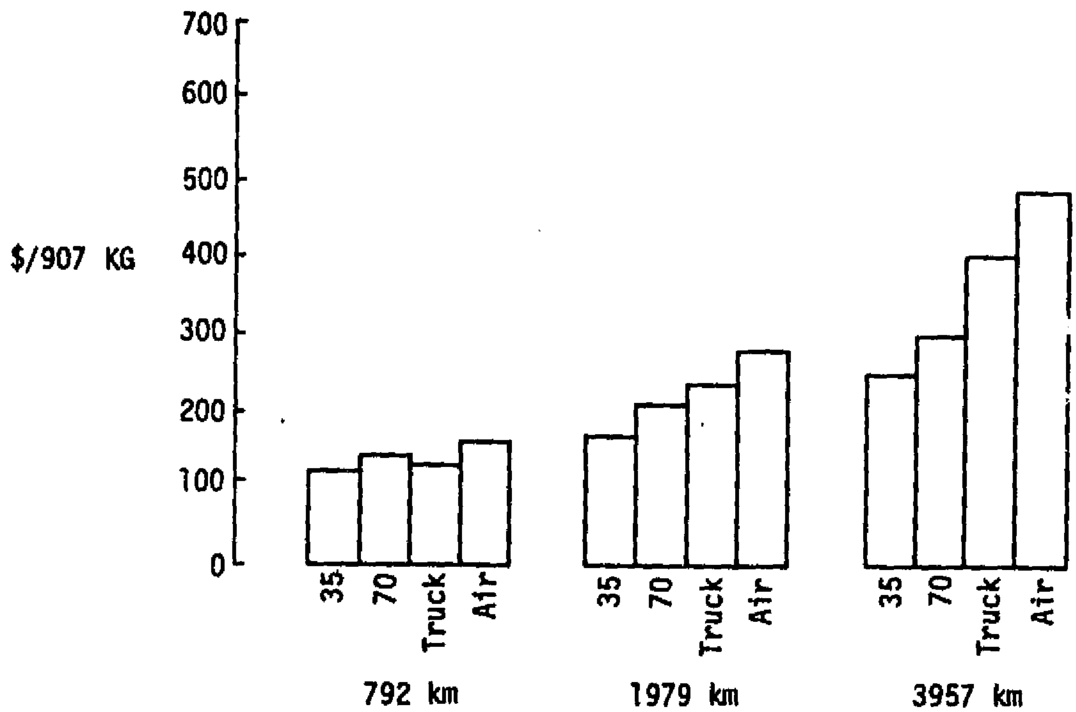

Figure 6-9. Total Costs With Air Pickup and Delivery and Terminal Costs Assumed to Equal Truck Pickup and Delivery and Terminal Costs

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Table 6-24

COMPARATIVE TOTAL COSTS IN DOLLARS - AIR PICKUP AND DELIVERY AND TERMINAL COSTS ASSUMED TO EQUAL TRUCK PICKUP AND DELIVERY AND TERMINAL COSTS

	Distance in Kilometers				
	792	1320	1979	2638	3957
Air	158.68	218.24	281.75	349.97	486.72
Truck	118.97	161.65	214.96	268.27	374.95
Air/Truck	1.33	1.35	1.31	1.30	1.30
Air	158.68	218.24	281.75	349.97	486.72
Mixed Train	137.03	156.97	191.43	216.33	275.55
Air/Train	1.16	1.39	1.47	1.62	1.77
Air	158.68	218.24	281.75	349.97	486.72
Through Train	109.49	129.87	155.32	180.35	231.55
Air/Train	1.45	1.68	1.81	1.94	2.10

The structure of the airfreight business is largely responsible for high air terminal costs. Present airfreight marketing encourages shippers to deliver freight very close to flight time causing substantial terminal peaking problems. Present air terminals were designed to meet the needs of aircraft, not the other way around, causing substantial terminal inefficiencies. When these problems are combined with the high level of service afforded by airfreight, the result is high terminal costs. High terminal costs can be justified on long stage length flights where line haul costs are high relative to terminal costs. However, high terminal costs are less justifiable on flights of shorter stage lengths as can be seen in Figure 1-30 of Volume I.

The air mode of freight transportation has had approximately 30 years to mature. It usually takes approximately 75 years for a transportation mode to

mature. The air mode is presently characterized by high pickup and delivery and terminal costs which have been exchanged for handling speed. As the air mode matures, it can be hypothesized that the air mode will sacrifice some handling speed in exchange for lower pickup and delivery and terminal costs. Recent air cargo deregulation might hasten this exchange and lower the time required for airfreight maturity.

Each mode faces similar terminal, and pickup and delivery tradeoffs. There is less flexibility in line-haul substitutions. As can be seen from Table 6-25, airline haul is more fuel and capital intensive than other modes. Consequently, fuel rationing and/or fuel price increases would affect the air mode more than other modes given no change in technology. Air fuel-efficiency technology presently under development at NASA and elsewhere is of great importance to the airfreight industry. The capital intensiveness of the air industry will increase over time since new air technology tends to substitute capital for other inputs. Luckily, air capital costs have increased less than most other freight costs.

Table 6-25
PERCENTAGE LINE HAUL COSTS BY INPUT

Mode	Fuel	Labor	Capital	Maintenance
Air	28	19	40	13
Truck	8	61	20	11
Rail 70	14	20	38	28
Rail 35	15	27	24	34

The labor intensiveness of airline haul is less than that of the other modes. Remembering that the air mode costs presented pertain to narrow-body aircraft, this disparity will increase as wide-body aircraft are substituted for narrow-body aircraft. Noting that transportation labor costs tend to increase more rapidly than most other costs, the air mode is fortunate that

airline haul costs are not labor intensive. Air and truck line haul maintenance intensities are comparable. Rail line haul is presently very maintenance intensive. If the railroads get their houses in order, this situation will change and the rail mode will become more competitive.

International Cost Comparison

The line haul costs associated with the transportation of high-value, low-density freight between New York and the U.K. and the U.K. and Japan are examined. For each market, three types of transportation are compared. Douglas DC-8-63F and Boeing 747 aircraft are compared to container ships of the most efficient sizes (Reference 6-9). These line-haul vehicles are described below.

Air: DC-8-63F, Volume 301.4 m^3, Design Density 135.4 kg/m^3
Boeing 747-100F, Volume 782 m^3, Design Density 124.7 kg/m^3

Water: N.Y. - U.K. Route 1250 TEU container ship
U.K. - Japan Route 2500 TEU container ship

Note: A 1250 TEU (20-foot equivalent unit) container ship is a vessel capable of hauling 1250 containers each 2.44 X 6.10 m. The internal volume of each container is 29.7 m^3.

Air mode costs are from Flying Tiger Line records and should be considered to be accurate 1977 costs. Container ship costs are from Reference 6-9. Ship costs were inflated to 1977 levels using information from the same source. More accurate deep-sea shipping cost information could be developed through the use of city-pair simulation models (e.g., Reference 6-10) if more time and resources were to be made available.

The container ships costs considered are U.K. American container ship costs are of little interest since American deep-sea shipping is subsidized by the U.S. government to the extent necessary to make U.S. costs comparable to foreign costs. The operating differentital subsidy given American deep-sea shipping often amounts to approximately 50 percent of capital costs.

Air versus deep-sea shipping subsidies are an interesting anticompetitive paradox. The U.S. government subsidized U.S. deep-sea shipping so it can compete with foreign deep-sea shipping. The U.S. government has also financed U.S. aircraft purchased by foreign firms or governments at low interest rates to encourage the sale of U.S. aircraft. However, the U.S. government has never subsidized U.S. air cargo in any manner. These subsidy differentials jeopardize the competitive position of American carrier international air cargo. For a more detailed subsidy discussion, see Volume I, Section 5.

An understanding of air versus deep-sea shipping system and equipment constraints, operational procedures and conditions, and data reporting methods is basic to an objective assessment and comparison of the modes. The few key differences are considered here are line haul cost elements, density, and circuity.

Line haul cost elements. - Air cargo is delivered, either directly or through an agent or forwarder, to air terminals where it is consolidated and loaded on aircraft. At the destination, this freight is broken down at the air terminal and delivered to the consignee either directly or through an agent of forwarder. The deep-sea shipping point of consolidation and breakdown for high-value, low-density freight is at ocean freight forwarders, not port terminals. As is illustrated in Figure 6-10, deep-sea shipping line haul is considered to be from forwarder to forwarder for mode comparison purposes.

Density. - Deep-sea shipping is limited by volume not weight. The cost per ton of shipping low-density freight by container ship is based on volume as determined from effective density and wieght. Effective density for deep-sea shipping, based on Reference 6-9, is 366.8 kg/m^3 and for airfreight, based on Reference 6-1, is 90.45 kg/m^3.

Any effective density could be used as the basis for comparison between modes without affecting the relative modal costs providing each mode is capable of carrying freight of the chosen density including variances from the average; the design density of a B747-100 is 124.7 kg/m^3. An effective density of 90.45 kg/m^3 is used as the basis for comparison.

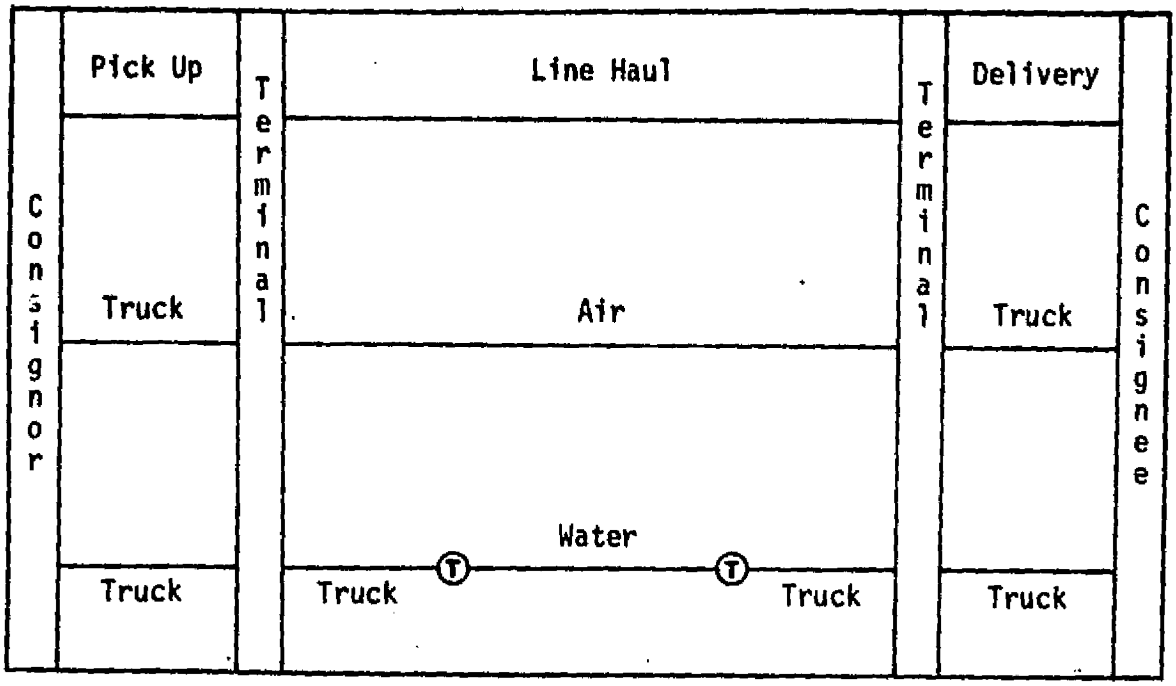

Figure 6-10. Line-Haul Cost Elements

Circuity. - Distance bookkeeping differs by mode. Air data give credit only for great circle distance while deep-sea data give credit for the rate-making distance. The rate-making distance overstates the transportation service provided. The ratio of rate-making distance to great circle distance is a measure of circuity (different from the one used in the domestic cost comparison). Circuities of this type are presented below.

New York to U.K.	5.9 percent
U.K. to Japan	
Air via Anchorage	33.4 percent
Containership via Panama	162.7 percent

Total costs. - The dollar cost of transporting 907 kg of freight between New York and the U.K. and the U.K. and Japan, given measured effective freight densities, is presented in Figure 6-11 and Table 6-26. The cost of air transportation is from 8.38 to 15.46 times deep-sea shipping costs. These

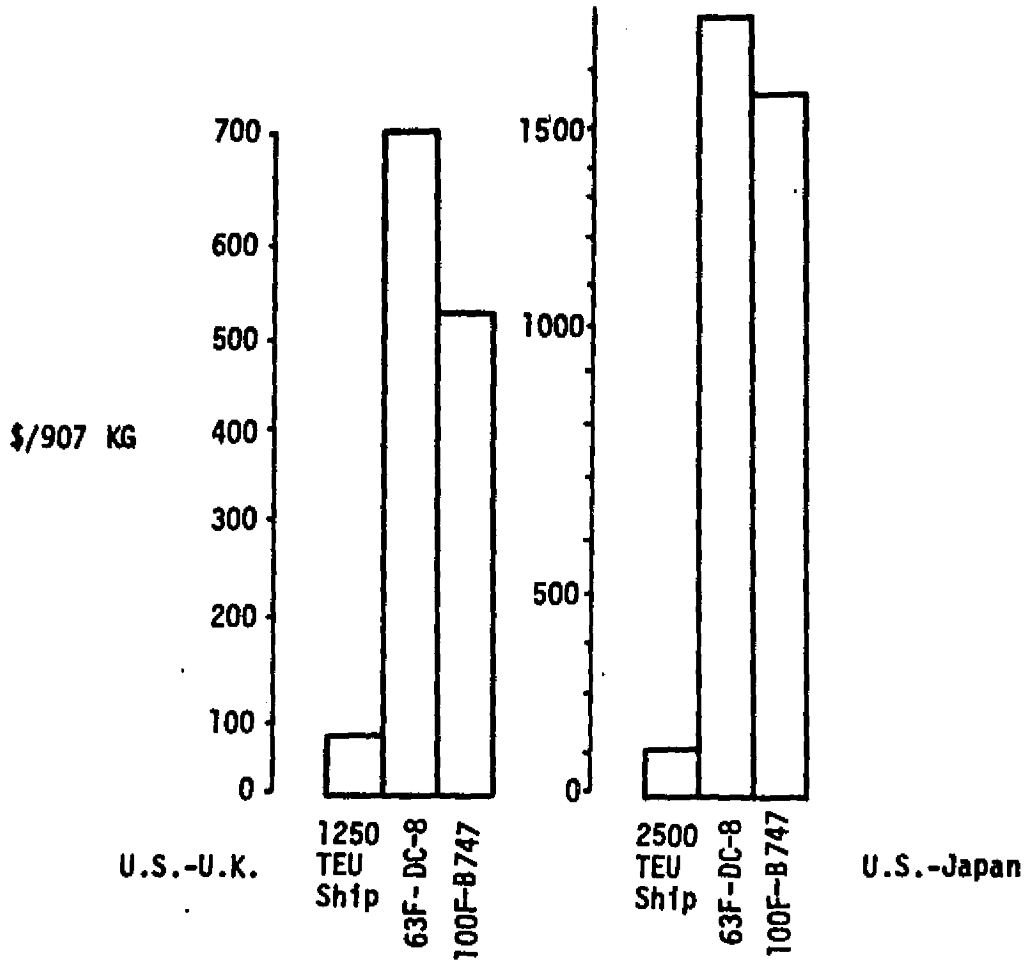

Figure 6-11. Comparative Total Costs, No Adjustments

TABLE 6-26

COMPARATIVE TOTAL COSTS IN DOLLARS/907 kg
UNADJUSTED

Route	U.S.-U.K.	U.K.-Japan
GC km	5376	9585
DC-8	696.25	1624.07
Ship	62.80	105.07
DC-8/Ship	11.09	15.46
B747	526.45	1482.77
Ship	62.80	105.07
B747/Ship	8.38	14.11

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unadjusted comparative total cost ratios indicate the air mode's large level of service advantage is accompanied by a large cost disadvantage.

A similar comparison given a common effective freight density of 90.45 kg/m^3 is presented in Figure 6-12 and Table 6-27. These adjustments result in a substantial reduction in the relative cost of air transportation. The cost for a B747 is 2.07 times that for a 1250 TEU (20-foot equivalent unit) containership between New York and the U.K. and 3.48 times that of a 2500 TEU containership between the U.K. and Japan. The DC-8 is somewhat less efficient on these routes. However, its smaller size might justify the higher per 907 kg costs because of indivisibilities. It is impossible to fly one-half of a B747. A thorough analysis of the adjusted costs are presented in the following paragraphs.

Fuel labor, capital, and maintenance costs, and insurance and landing fees, and port charges. - Modal fuel, labor, capital, and maintenance costs, and insurance costs, landing fees and port charges are presented in Figure 6-13 and Table 6-28. With the exceptions of labor, insurance, landing fees, and port charges for a B747 on the New York-to-U.K. route, airplanes use more of each input per 907 kg of weight than container ships do.

It is informative to compare the cost of inputs by route. Aircraft use from 5.1 to 7.6 times as much fuel on the New York-to-U.K. route as ships do but only 3.2 to 3.9 times as much on the U.K.-to-Japan route. This difference is primarily due to the extreme circuity connected with passage through the Panama Canal. A reverse comparison holds with respect to labor. Aircraft use from 0.9 to 1.7 times as much labor on the New York-to-U.K. route and from 3.1 to 5.0 times as much on the U.K.-to-Japan route. This large difference is mostly due to high stevedoring costs, especially in New York.

Aircraft use from 2.0 to 2.2 times as much capital on the New York-to-U.K. route as ships do and from 2.5 to 3.2 times as much on the U.K.-to-Japan route. This difference is primarily due to the economics of scale connected with a 2500 TEU vessel compared to a 1250 TEU vessel and the inverse relation between port time importance and voyage length. Aircraft use from 10.4 to 13.7 times as much maintenance and repair on the New York-to-U.K. route as

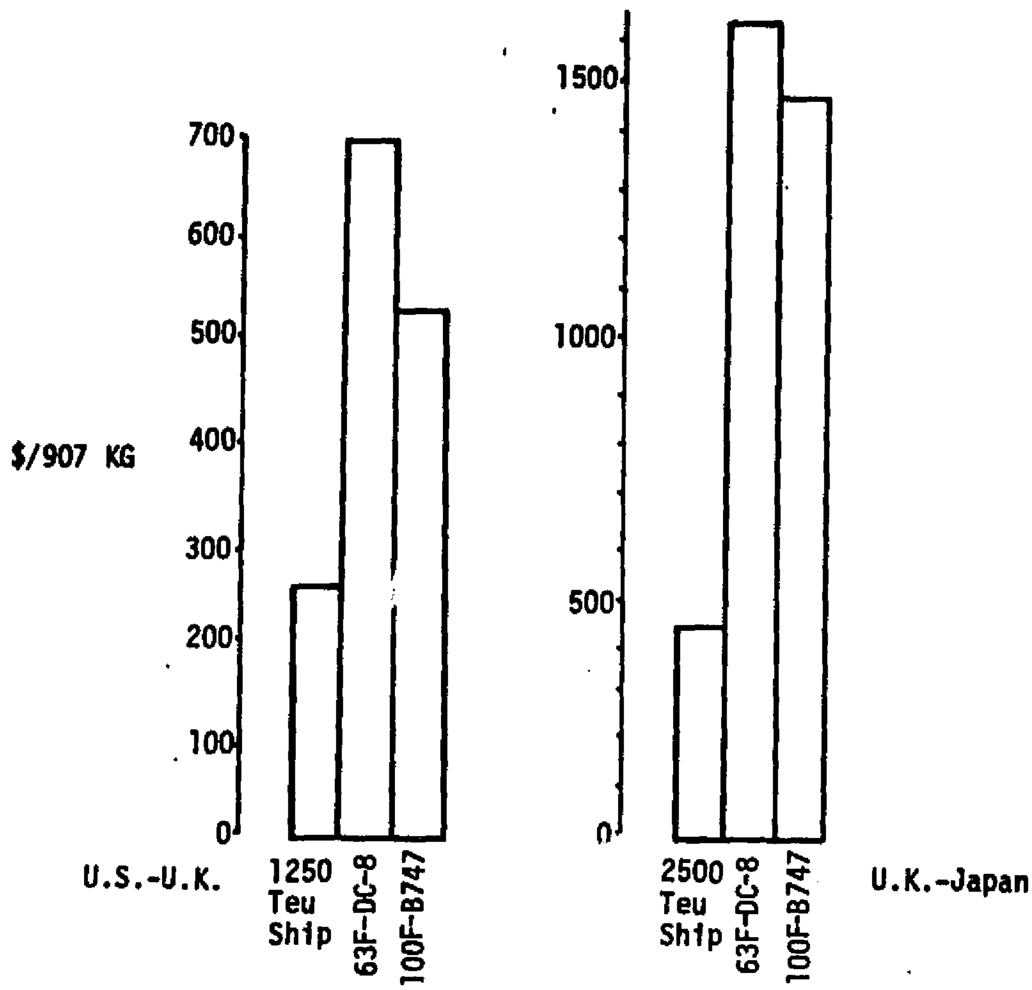


Figure 6-12. Comparative Total Costs With Density Adjustment

TABLE 6-27

COMPARATIVE TOTAL COSTS IN DOLLARS/907 kg
WITH DENSITY ADJUSTMENT

Route	U.S.-U.K.	U.K.-Japan
GC km	5376	9585
DC-8	696.25	1624.07
Ship	254.64	426.05
DC-8/Ship	2.73	3.81
B747	526.45	1482.77
Ship	254.64	426.05
B747/Ship	2.07	3.48

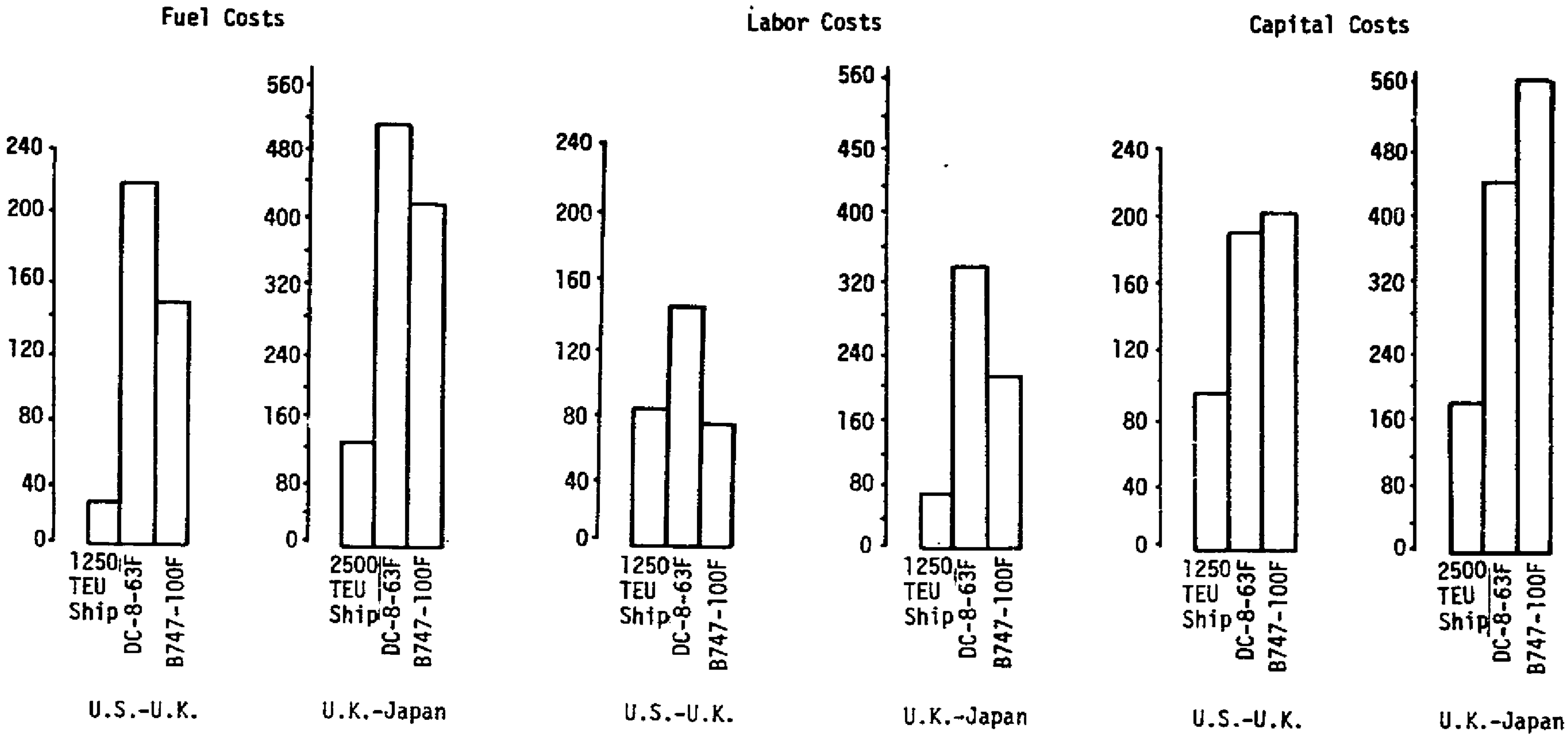
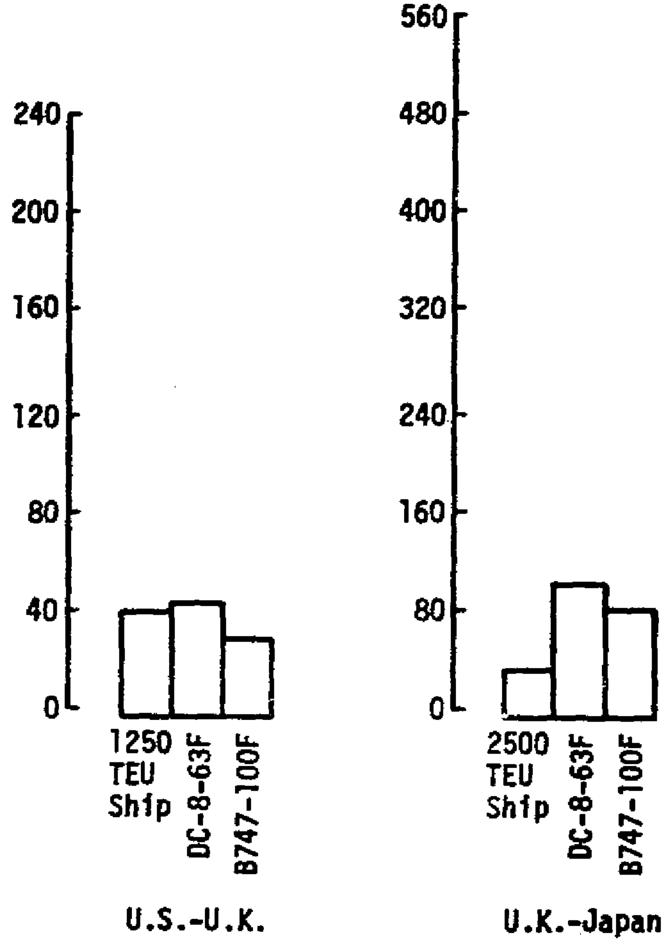


Figure 6-13. - Total Cost Comparison - Surface vs Air ($/907 KG)

Insurance, Landing Fees, and Port Charges



Maintenance Costs

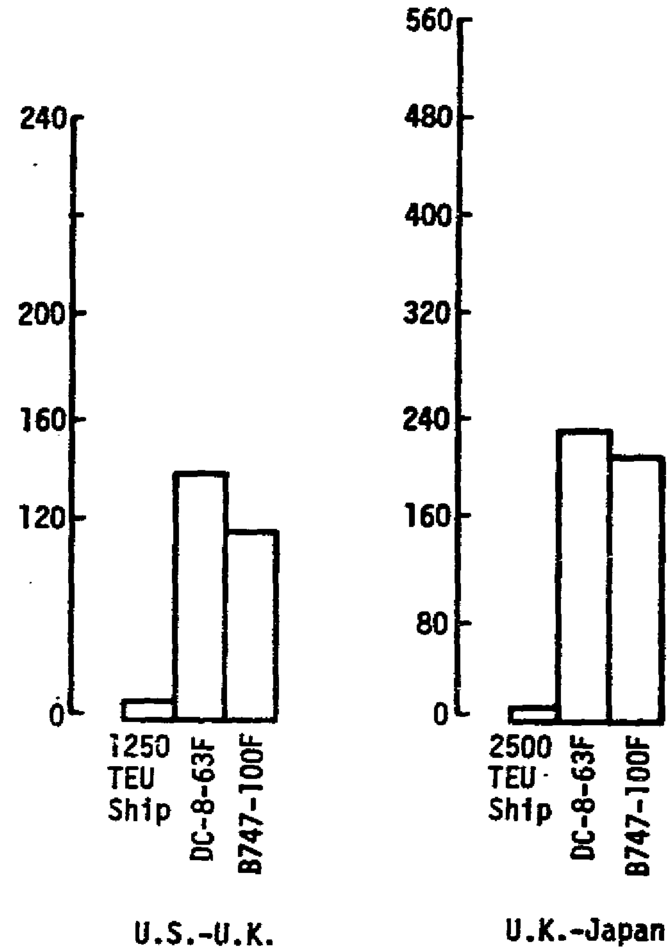


Figure 6-13. Concluded ($/907 KG)

TABLE 6-28

AIR VERSUS CONTAINERSHIP LINE-HAUL COSTS IN DOLLARS/907 KG

	Line Haul	Fuel	Labor	Capital	Maintenance	Insurance Landing Fees Port Charges	Route
DC-8-63F	696.25	219.80	143.54	189.16	98.62	45.14	U.S. - U.K.
1250 TEU	254.64	28.82	82.90	93.92	7.18	41.81	U.S. - U.K.
DC-8/1250	2.7	7.6	1.7	2.0	13.7	1.1	U.S. - U.K.
B747/100F	526.45	146.35	73.58	201.75	74.61	30.16	U.S. - U.K.
1250 TEU	254.64	28.82	82.90	93.92	7.18	41.81	U.S. - U.K.
B747/1250	2.1	5.1	.9	2.1	10.4	0.7	U.S. - U.K.
DC-8-63F	1624.07	513.05	335.03	440.58	230.18	105.23	U.K. - Japan
2500 TEU	426.05	130.64	66.37	178.57	11.78	38.69	U.K. - Japan
DC-8/2500	3.8	3.9	5.0	2.5	19.5	2.7	U.K. - Japan
B747/100F	1482.77	412.22	207.28	568.25	210.09	84.93	U.K. - Japan
2500 TEU	426.05	130.64	66.37	178.57	11.78	38.69	U.K. - Japan
B747/2500	3.5	3.2	3.1	3.2	17.8	2.2	U.K. - Japan

ships do and from 17.8 to 19.5 times as much on the U.K.-to-Japan route. This indicates that ships are either relatively maintenance free when compared to airplanes or that ships are very poorly maintained: Hopefully it is the former.

Aircraft use from 0.7 to 1.1 times as much insurance, landing fees, and port charges on the New York-to-U.K. route as ships do and from 2.2 times as much on the U.K.-to-Japan route. This large difference is primarily due to high port charges, especially in New York.

Percentage fuel, labor, capital, maintenance and insurance, landing fees, and port charges are presented in Figure 6-14 and Table 6-29. A route-by-route analysis of these data is again informative. On the U.S.-to-U.K. route, aircraft are from 2.55 to 2.82 times as fuel intensive as ships. However, on the U.K.-to-Japan route, aircraft are only 0.90 to 1.03 times as fuel intensive. This difference can be attributed to the fact that "...fuel now accounts for over 60 percent of the daily operating (including capital) costs of a 2500 TEU vessel" (Reference 6-9, page 3), and in deep-sea shipping, daily operating costs gain in importance as the length of the voyage increases.

Aircraft are from 0.42 to 0.64 times as labor intensive as ships are on the New York-to-U.K. route but 0.88 to 1.31 times as labor intensive on the U.K.-to-Japan route. This difference is due to the importance of high stevedoring labor costs and low daily operating costs in deep-sea shipping. On the New York-to-U.K. route, only 6.4 percent of daily operating (including capital) costs for a 1250 TEU vessel are labor costs.

On the N.Y.-to-U.K. route, airfreight is from 0.70 to 1.03 times as capital intensive as deep-sea shipping. On the U.K.-to-Japan route, airfreight is from 0.64 to 0.90 times as capital intensive. This difference is indicative of the economics of scale involved in deep-sea shipping. The absolute size of the numbers indicates that deep-sea shipping is generally more capital intensive than the capital intensive airfreight industry. The intensiveness of maintenance does not vary by route. Airfreight is 4.67 times as maintenance intensive as deep-sea shipping. Aircraft on the N.Y.-to-U.K.

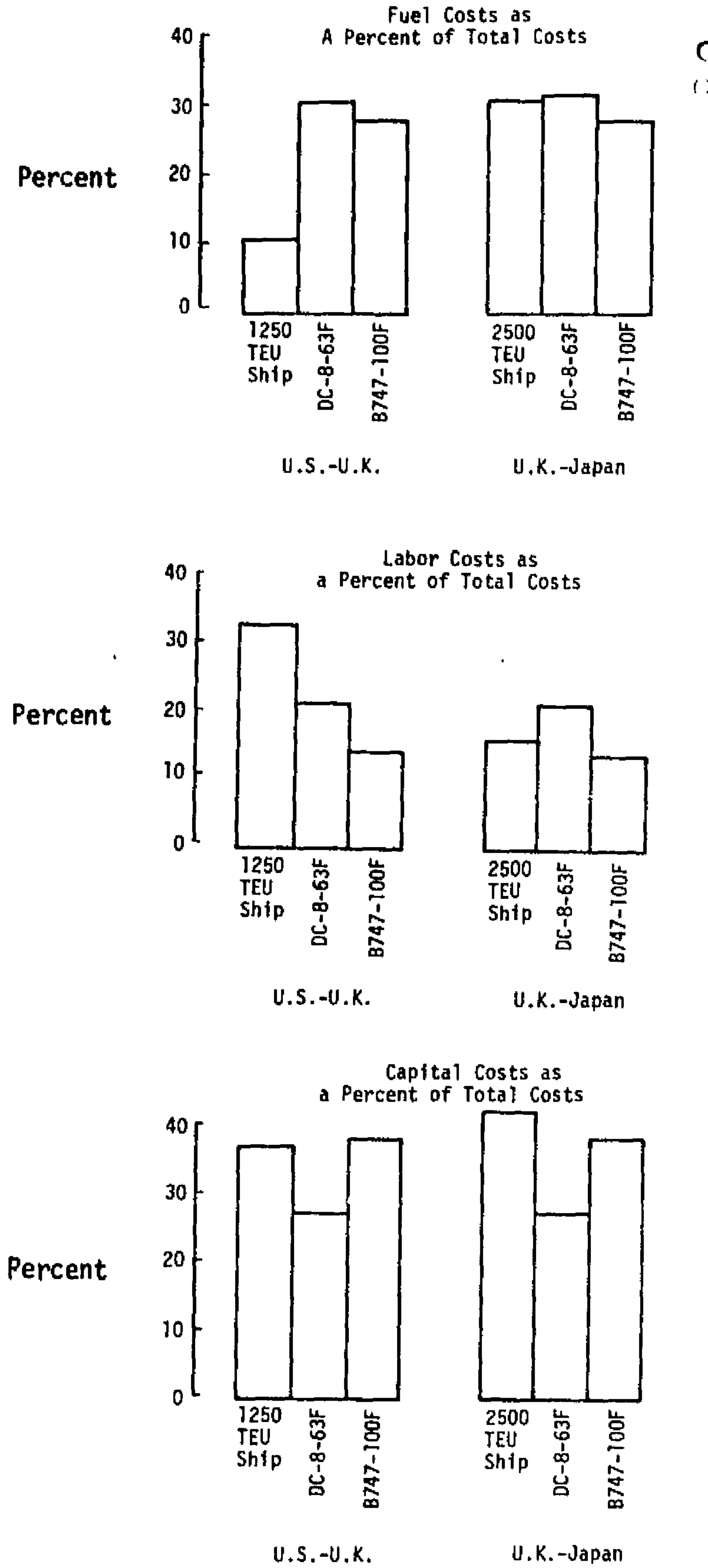
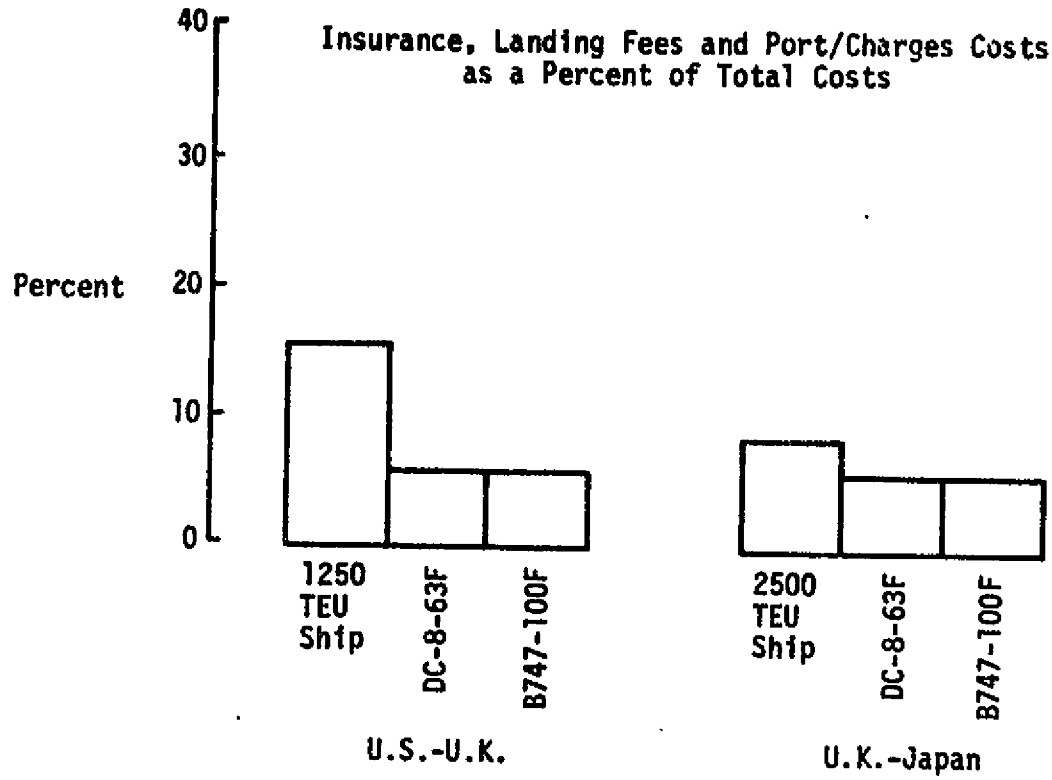


Figure 6-14. Percentage of Total Costs



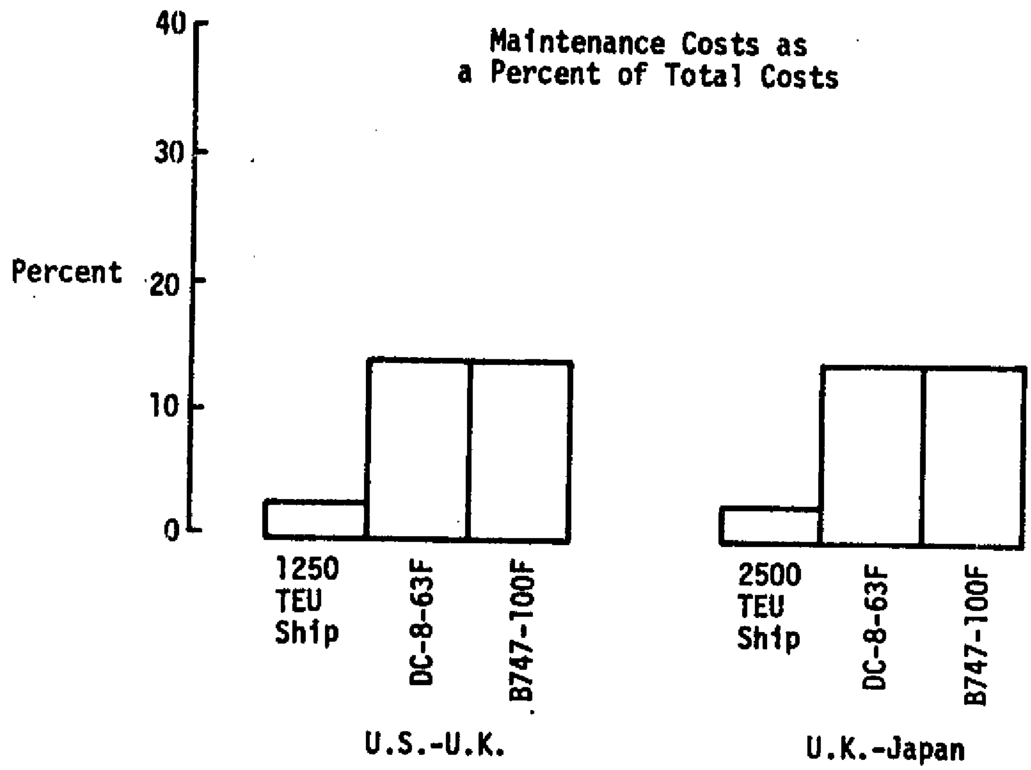


Figure 6-14. - Concluded

TABLE 6-29

AIR VERSUS CONTAINERSHIP LINE HAUL COSTS AS A PERCENT OF LINE HAUL COSTS

	Line Haul (Dollars)	Fuel	Labor	Capital	Maintenance	Insurance Landing Fees Port Charges	Route
DC-8-63F	696.25	31	21	27	14	6	U.S. - U.K.
1250 TEU	254.64	11	33	37	3	16	U.S. - U.K.
DC-8-1250	2.7	2.82	0.64	0.73	4.67	0.38	
B747/100F	526.45	28	14	38	14	6	U.S. - U.K.
1250 TEU	254.64	11	33	37	3	16	U.S. - U.K.
B747/1250	2.1	2.55	0.42	1.03	4.67	0.38	
DC-8-63F	1624.07	32	21	27	14	6	U.K. - Japan
2500 TEU	426.05	31	16	42	3	9	U.K. - Japan
DC-8/2500	3.8	1.03	1.31	0.64	4.67	0.67	
B747/100F	1482.77	28	14	38	14	6	U.K. - Japan
2500 TEU	426.05	31	16	42	3	9	U.K. - Japan
B747/2500	3.5	0.90	0.88	0.90	4.67	0.67	

route are 0.38 times as insurance and landing fee intensive as deep-sea vessels are insurance and port charge intensive. The corresponding figure for the U.K.-to-Japan route is 0.67. This difference can be attributed to the significance of port charges on shorter deep-sea voyages and high New York port charges.

International cost comparison conclusions. - The air mode's large level of service advantage is accompanied by a large cost disadvantage. Distance tends to accentuate this difference due to the significance of stevedoring costs and port charges on shorter deep-sea voyages.

The fuel, labor, and capital intensiveness of a B747 and a 2500 TEU container ship ar remarkably similar for long voyages. Consequently, as fuel, labor, and capital costs change in the future, the cost position of a B747 relative to a 2500 TEU containership should remain relatively constant for long voyages. When compared to the other options, the DC-8 option represents a substitution of fuel and labor intensiveness for capital intensiveness. Consequently, the DC-8 can be expected to become less competitive on long voyages in the long-run if fuel and labor costs continue to increase more rapidly than capital costs.

In terms of fuel, labor, and capital, the B747 is more fuel intensive, less labor intensive, and almost equal in capital intensity when compared to a 1250 TEU containership on short voyages. Consequently, the relative cost position of the B747 depends on increases in fuel costs relative to labor costs. If fuel price increases continue to outpace labor price increases, the B747 will become less cost competitive compared to a 1250 TEU containership on short voyages in the long run. When compared to a B747, the DC-8 option represents a substitution of fuel and labor intensiveness for capital intensiveness. Consequently, the DC-8 can be expected to become less competitive on short voyages in the long-run if fuel and labor costs continue to increase more rapidly than capital costs.

Containerships are more insurance, landing fee, and port charge intensive than aircraft, especially on shorter voyages. The landing fee and port charge cost segments of this classification have been increasing much faster than

other costs (see Volume 1, Section 5). Since containerships are more port charge intensive than aircraft are landing fee intensive, port charge and landing fee increases can be expected to improve the relative cost position of aircraft given equal percentage increases in landing fees and port charges.

All of the above is predicated on the dollar holding its value relative to the currencies of countries providing deep-sea shipping alternatives. If the dollar continues its relative decline in value, the comparative cost position of U.S. provided air cargo will improve.

SECTION 7
ELASTICITIES OF DEMAND

During the past 6 years, the air cargo industry has shown dramatic changes. Revenue tonne-kilometers have grown at a 5 percent rate domestically and at a 9 percent rate internationally. International foreign markets have grown at the astonishing rate of 14 percent per year. Tariffs (rates) have declined 1.6 percent per annum in real terms. These are, indeed, big changes. During the next 12 years, the air cargo industry probably will experience equally dramatic changes. The scene already has been set by deregulation of the domestic air cargo industry, the growing use of containerization, and the introduction of new large air cargo aircraft,e.g., the B747F. These changes immediately raise the question of the dedicated air freighter. Is it "an idea whose time has come?"

To establish the real-world feasibility of a dedicated air freighter, it is necessary to examine the past to determine the relations among the various elements shaping the economics of the air cargo industry: the demand patterns, the cost structure, the infrastructures supporting the industry, the attitudes of both users and operators, the role of service, as well as the airplanes in current usage. The analysis of the relations among these elements has been set into a dynamic context in this and the three suceeding sections to illuminate the consequences of major developments in the past and to suggest what the consequences of potential future changes may be. These analyses will form a basis for projecting the probable future state of the air cargo industry.

Market Rate and Service Elasticity

Earlier in this volume (Section 2), three econometric scenarios are presented for domestic airfreight growth. The baseline scenario (2) reflects the economic consequences of a constant airfreight-to-truck-freight yield ratio, resulting in a 1976 to 1990 growth factor of 3.34 times in revenue tonne-kilometers and 3.44 times in revenue tonnes. The more optimistic scenario (1) with an air-to-truck rate yield ratio declining at 2 percent per annum results in growth factors of 4.48 in revenue tonne-kilometers and 4.56 in revenue tonnes. A pessimistic scenario (3) with the

air-to-truck freight rate yield ratio increasing at 2 percent per annum, provides a 2.56 growth factor in revenue tonne-kilometers and a 2.60 growth factor in revenue tonnes. The tonne growth factors were calculated using the weighted average domestic and United States international stage lengths provided in Section 4. The objective of this section demands a more explicit treatment of the role of price and service in the future scenario than is considered in Section 2. Consequently, a more detailed (disaggregated) model was developed to handle these issues. The primary difference between this sensitivity model and the large econometric model of Section 2 is that the air/truck rate/service variables have been made more explicit.

Rate elasticity. - The model and, indeed, the earlier econometric models belong to a general class of descriptive models called elasticity models. Elasticity in general terms is the percentage change of demand anticipated as the result of a percentage change in some causative variable. For example, if the yield elasticity is minus one, it is anticipated that every 1 percent decrease in the yield will result in a 1 percent increase in revenue tonne-kilometers. Demand can, of course, be influenced by other variables in addition to prices. Some of these variables are gross national product (or personal income), level of service, and the prices charged by competing modes. Price elasticity is defined over the interval from 0 to minus infinity. If the elasticity is 0, the demand for a commodity is totally fixed without reference to price or, for that matter, any other factor that has a zero elasticity. At a price of 0, just as much is demanded as at an infinitely high price and demand is perfectly price inelastic. On the other hand, and at the other end of the spectrum ($-\infty$) there is, at least theoretically, a perfectly elastic case. The price is fixed, and the market will accept all that can be produced. When the elasticity coefficient is unity (minus one) the market is neither elastic nor inelastic. If the elasticity is less than unity, for example say -0.75, a decrease in price or a decrease in any other variable will not add as much revenue, by increased demand, as it will lose by reduced price. In the other case, when the elasticity is greater than unity, a price reduction will add more revenue, by increased demand, than was lost by the price reduction. This notion of elasticity is key to the discussion.

Two explicit models were constructed to examine elasticity issues using United States domestic data. These models were constrained to United States data because data describing the service offered by the competing international mode and ships were not available.

Each United States domestic model used a different definition for the gross service offered by the air cargo industry. The first all-jet model used as a measure of service the number of three- and four-engine jet aircraft in service in the United States in each year. This number was suitably adjusted to approximately reflect the cargo-carrying capacity of both wide- and narrow-body jet aircraft. The second, wide-body model, used as a measure of service the number of wide-body jet aircraft available for service in the United States in each year. Two-engine aircraft were excluded from both models because they have relatively limited cargo capability. The analysis did not limit itself to only the number of all-cargo jet aircraft in service in the United States because many jet aircraft could be operated in a convertible cargo/passenger configuration. In the past, many operators used this capability; but, in later years, convertible aircraft have been operated primarily in a cargo configuration. To limit historical analysis to all cargo aircraft would have overstated the service growth factor.

The gross service characteristics of the demand elasticity model were incorporated in the yield variable. The econometric model discussed in Section 2 found an optimized 20 percent weighting for service. Therefore, 20 percent of the air service factor was subtracted from the constant dollar yield so that the yield/service variable actually used is a "net" variable, i.e., improved service reduces perceived cost. The truck yield variable was treated similarly. The intrastate network mileage, suitably scaled, was subtracted, in turn reducing the constant dollar truck yield. The same optimized 20 percent factor was used:

$$\text{Adjusted Yield} = \text{Constant Yield} - 0.2\ (\text{Service Factor})$$

There is an important distinction between the two models. The all-jet model more nearly reflects the capability for all-freighter service because there are significant numbers of all jet freighter aircraft services in the

United States today. The major trunk carriers operate a large number of dedicated jet freighters, but there are only a few wide-body all-jet freighters in domestic service today. Therefore, the wide-body model represents not the dedicated and presumably highly time-dependent air cargo service but rather the service associated with movement of cargo during the day time in wide-body aircraft.

The general form of the models is:

$$\ell n\ D_i = \exp\left(C + \bar{\varepsilon}_1\ S_{50i} + \bar{\varepsilon}_2\ \ell n\ Yff_i/Ya\ell_i + \bar{\varepsilon}_3\ \ell n\ GNP_i + \bar{\varepsilon}_4\ \ell n\ AIR_i + \bar{\varepsilon}_5\ \ell n\ TRUCK_i\right)$$

where D = Demand in revenue tonne-kilometers

i = i th year

S = 0 before Hawaii and Alaska data were consolidated into domestic demand data, 1 thereafter

Yff = Yield of freight forwarders

$Ya\ell$ = Yield of air lines

GNP = Real (deflated GNP) lagged to form a permanent measure

AIR = Adjusted air cargo yield (deflated) less gross service factor

Yal -0.2 * Equivalent four-engine jet aircraft/100

Yal -0.2 * Equivalent four-engine wide-body jet has aircraft/100

TRUCK = Adjusted truck yield (deflated) less gross service factor

Yield Truck -0.2 * No. of miles in federal highway System/100

$\bar{\varepsilon}$ = Elasticity

* = Signifies multiplication

The all-jet model, which is statistically superior to the wide-body model, has been emphasized to illustrate the way the major variables influence domestic airfreight revenue tonne-kilometers and the demand for air cargo. Figure 7-1 displays airfreight demand growth as the function of gross

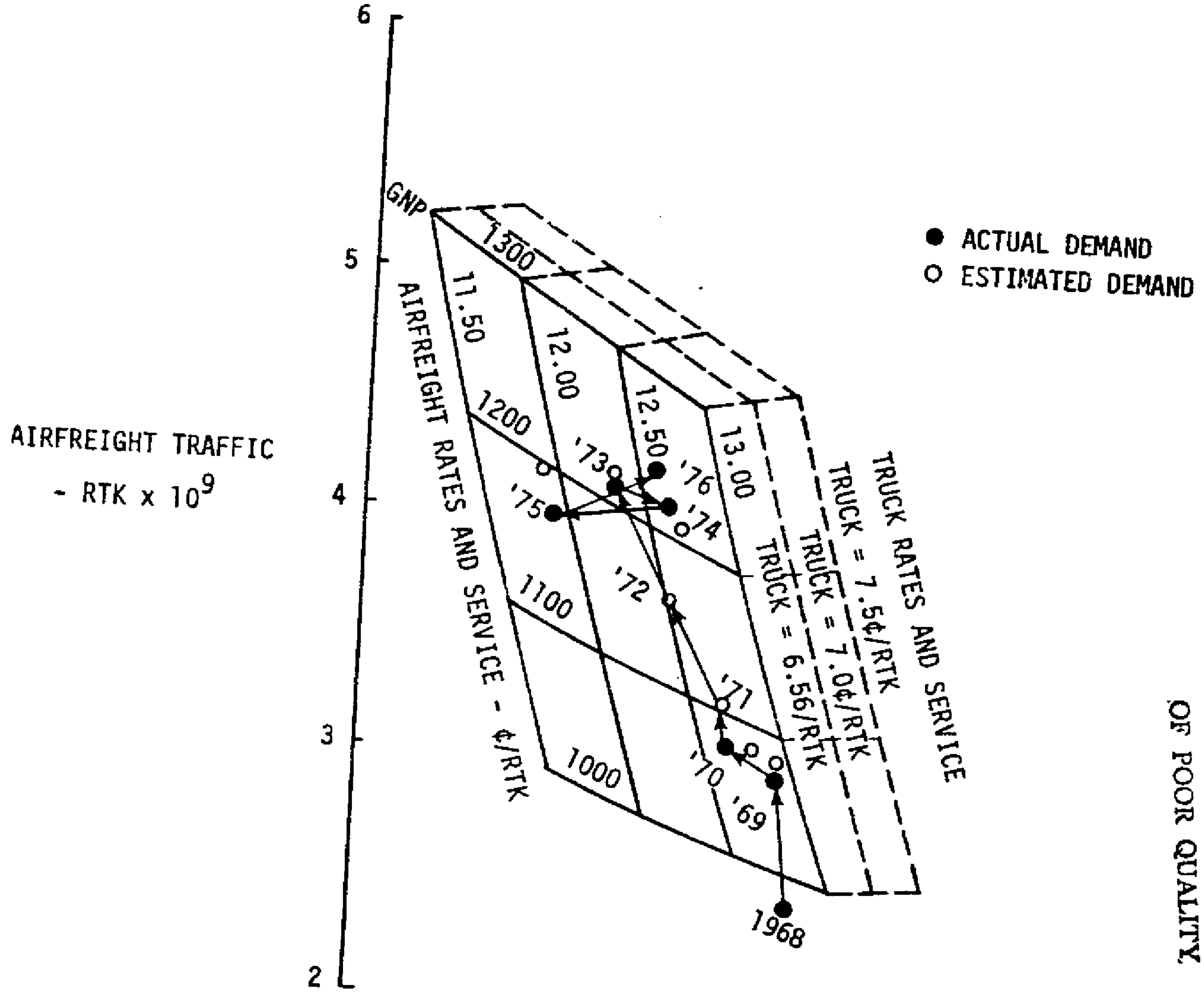


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Figure 7-1. Revenue Tonne-Kilometers as a Function of Gross National Product and Airfreight Rates and Services

national product, suitably deflated as discussed in Section 2, and constant airfreight yield and service. The other primary parameter is truck yield and service, which in the primary plane has been held constant at 6.5 cents per revenue tonne-kilometer. The historical CAB data trace on the face of the plane shows how air cargo has grown from 1968 to 1976. As gross national product has increased, revenue tonne-kilometers have increased. There was a steady decrease in real airfreight yield over the 1968 to 1973 time period. Since 1973, real domestic airfreight yield has behaved erratically. This contributed significantly to some of the variations in air cargo demand. All data are plotted on the primary (truck yield equals 6.5 cents) plane to make the presentation clearer. The phantom truck yield planes show that air cargo demand would increase only slightly with real truck yields. The actual air cargo demand is indicated by the solid points, while the model estimated air cargo demand is shown as open points in Figure 7-1. These graphically illustrate the very close correspondence between the model results and the actual results except for 2 years, 1974 and 1975. In these 2 years, the entire economy was undergoing quantum movements, largely as a result of the oil embargo of 1973 and 1974. Over the recent past, air cargo demand has been more influenced by a GNP growth and less significantly by changes in air cargo yield/service as indicated by the slopes of the GNP and air yield scales. This certainly supports the generally held thesis that historical demand for air cargo was relatively inelastic with respect to price. This is to say that a major reduction in air cargo yield, i.e., tariffs, did not induce strikingly larger increases in air cargo demand. This relation of prices and demand is central to the entire analysis and will be returned to time and again during the course of this discussion.

The calculated GNP elasticity of demand is +2.2 for the all-jet model shown in Table 7-1. This is to say that for every 1 percent increase in GNP, there is a 2.2 percent increase in air cargo demand. The wide-body model shows even greater elasticity with respect to GNP, the figure being 2.47. Both variables are highly significant in the model. In the all-jet model, the GNP variable has a "t" value of 6.3, i.e., greater than 6 sigma; while in the wide-body model, it has a value of 4.6, greater than 4 sigma. This shows that GNP is a less significant determinant of demand in the wide-body model.

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TABLE 7-1

DEMAND ELASTICITIES FOR THE ALL-JET AND WIDE-BODY MODELS

Parameter/Statistic		- Air Cargo Demand Sensitivity Models			
Name	Symbol	All-Jet Model		Wide-Body Model	
		Value	t	Value	t
Constant	C	-4.5052		-6.3105	
Elasticity					
50 State	$\bar{\varepsilon}_1$	0.1179	3.0640	0.1641	2.8456
GNPLAG	$\bar{\varepsilon}_3$	2.2072	6.3288	2.4694	4.6360
Air Mod (e)	$\bar{\varepsilon}_4$	-1.2748	-3.5861	-1.4965	-1.7860
Truck Mod (e)	$\bar{\varepsilon}_5$	0.1124	0.2990	0.4900	1.0257
Yff/Yal	ε_2	0.0936	0.4878	-0.2523	-1.2632
Coeff. Determination	ρ^2	0.9958		0.9923	
Standard Error	σ	0.0406		0.0555	
Significance	F	555.9630		297.4883	

The next most significant variable in the all-jet model is the elasticity coefficient of air rate/service of -1.27. This elasticity, which should not necessarily be interpeted literally, is much higher than estimated by some other small-scale models; but, in fact, it is very close to estimates of price elasticity published by government agencies. On the other hand, the air yield elasticity is -1.50 in the wide-body model. This disparity and the corresponding values of the other variables highlight the differences between the two models; price is a more important determinent of air cargo demand in the wide-body (daytime) market than in the all-jet market, an observation further supported by the truck price elasticity coefficients in the two models.

In the all-jet model, the truck yield/service variable has little significance and a very low price elasticity coefficient. In the wide-body model, while still not highly significant, truck yield has a far more important influence on air cargo demand. This suggests daytime service is more price competitive vis-a-vis truck than the higher quality all-cargo service offered at night. The coefficients of the forwarder to airline yield ratio have different signs for the two models. As the quality of service goes up in the all-jet market, the demand increases. However, in the wide-body market, the quality of service is not as important as the prices of the competing mode truck. Both models explain a very high degree of the variance of the data. Less than 1 percent of the variance is unexplained as shown by the coefficient of determination in Table 7-1.

The following listing provides the percentage change in demand that is predicted by each model for a 10 percent change in the indicated variables:

	All-Jet Model (%)	Wide-Body Model (%)
GNP	22	25
Air yield and service	13	15
Truck yield and service	1	5
Freight forward yield/airline yield	1	-3

Further analyses were made of both the wide-body and the all-jet markets. The approach was designed to determine if there were any trends in the data but not necessarily to determine the absolute values of calculated coefficiencies within the trends. The results correspond to a weighted moving average regression analyses. A set of elasticities were calculated for each year based upon a 5 year period. Data representing the middle 3 years were repeated, i.e., they appear as two sets of data instead of one.

The elasticity of GNP may be increasing, particularly since 1968. This is shown by both the all-jet and the wide-body model elasticities shown in Figure 7-2(a), i.e., the U.S. domestic economy may be showing a greater propensity to use airfreight as a result of real GNP increases. Elasticity of airfreight rate and service seems to be decreasing, that is, getting less negative. This is exhibited in Figure 7-2(b) for both the all-jet and the wide-body models since 1969. This suggests future real airfreight tariff reductions may have a smaller impact upon air cargo demand than they had in the past, i.e., that the market may becoming more price inelastic. This is contradicted by the truck tariff and service elasticities shown in Figure 7-2(c) where the market, as reflected through either model, is becoming more sensitive to truck tariffs. As truck tariffs decrease or service increases, the air cargo demand decreases. This contradiction suggests a more detailed study of elasticities may be in order (Reference 7-1). The suggested elasticity analysis of air cargo intraindustry competition, i.e., between the airlines and the freight forwarder, is inconclusive. Strong trends cannot be detected as shown by the data of Figure 7-2(d).

Earlier Douglas studies of the comparative price elasticities among air, truck, and rail modes in the United States showed that the demand for truck

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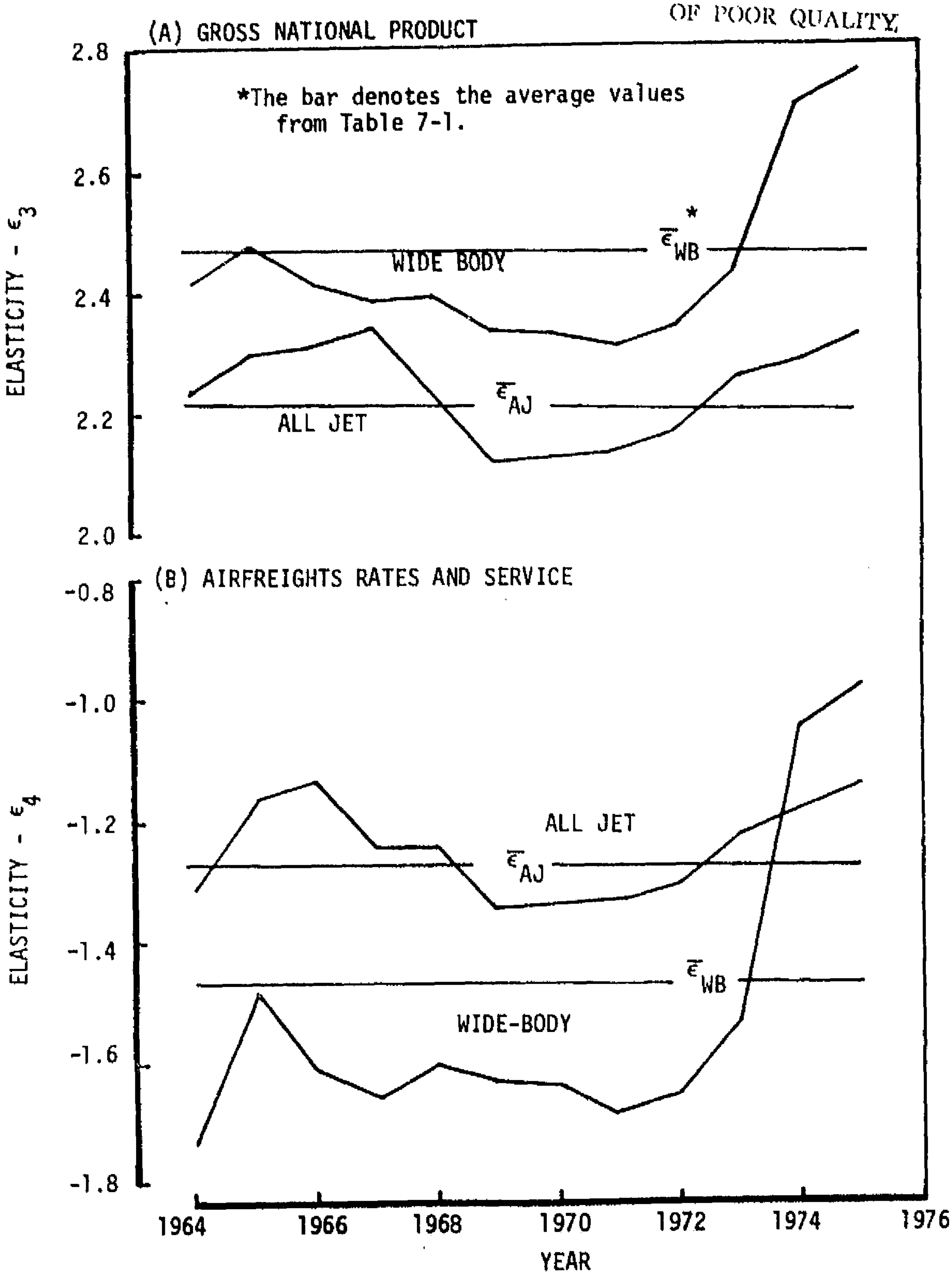

Figure 7-2. Elasticity Trends

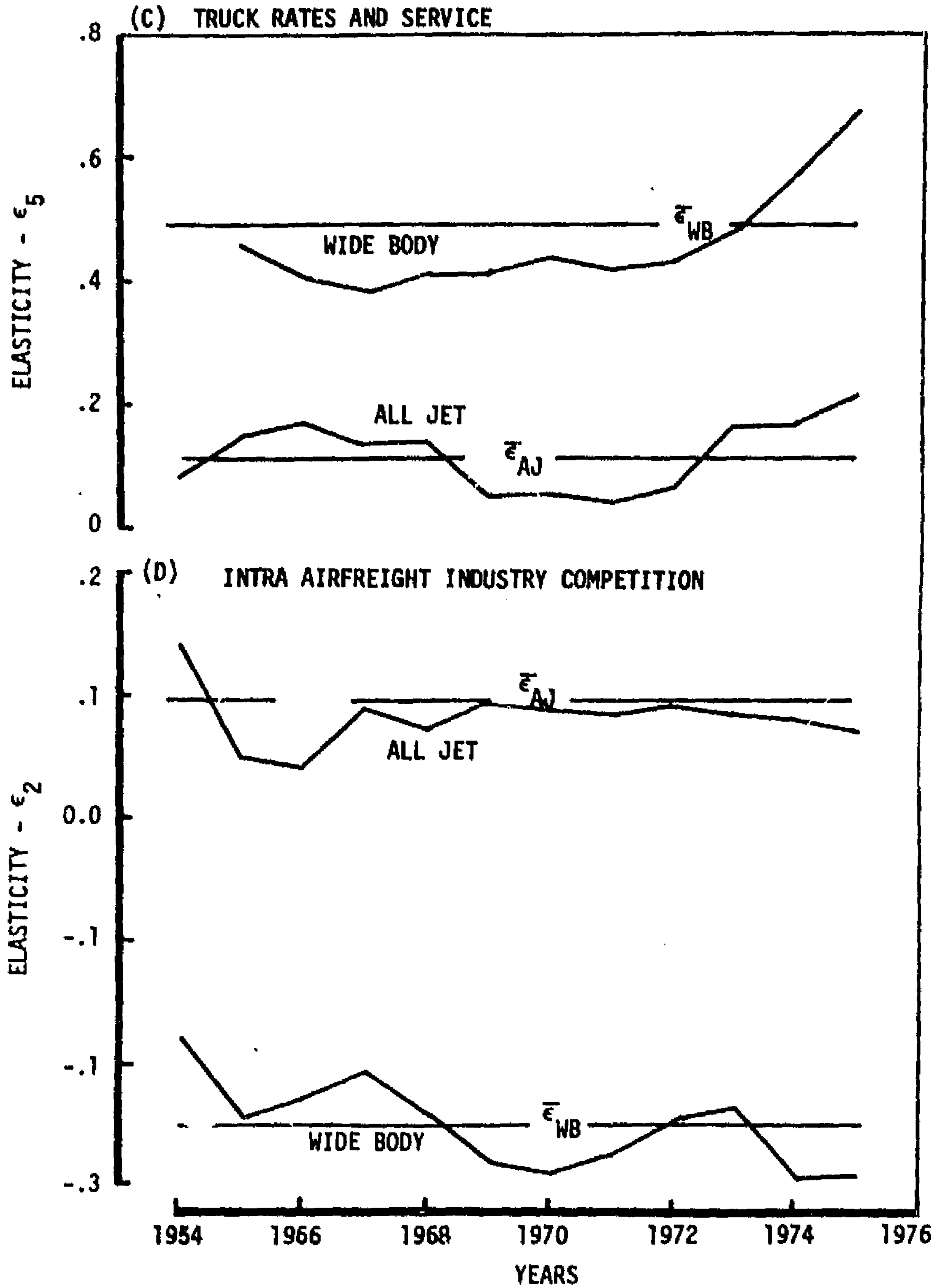

Figure 7-2. - Concluded.

transportation is much more highly price elastic then the demand for air transportation. The demand for rail transportation was practically price inelastic, a result that may be an obvious consequence of the market shares. Rail is the largest domestic freight mode but has grown relatively slowly since World War II with a resulting very small change in volumes carried. The relative changes in rail volume and air volume would make the price effects of air-cargo seem more important and, therefore, more price elastic. However many observers of the air cargo industry will say that airfreight is not very price sensitive (Reference 7-2). Historically, this may very well be true; however, the important issue is whether or not air cargo may be price sensitive in the future. This question is central to air cargo profits.

Service elasticity. - Another approach to determining at least relative elasticities was taken. This approach used a research technique known as conjoint measurement (developed from the fields of mathematical psychology and psychometrics) to produce utility measures of airfreight service attributes. The word "conjoint" refers to the characteristic of measuring the relative values of attributes considered jointly that might be unmeasurable individually.

The purpose of conjoint measurement is to quantify the relative importance of a product's multidimensional attributes and to use that quantification to predict buyer behavior relating to variations in those attributes. The underlying concept of the technique is that inferences about buyer behavior can best be made by measuring the way buyers make choices between various stimuli rather than by relying on their self-reported preferences. The statistical techniques used to convert these observed choices into utilities are similar to nonmetric scaling techniques. A frequently used method is an iterative procedure that minimizes a measure of the badness of fit of the utilities to the data. It is also possible to validate the ability of the resulting utilities to accurately predict buyer preferences.

Figure 7-3 presents the results of a sensitive commercial market research study; the ordinate is a normalized measure of relative utility. As the time required to deliver a shipment increases, the utility of air decreases; and, as the tariff for that shipment increases, the utility of

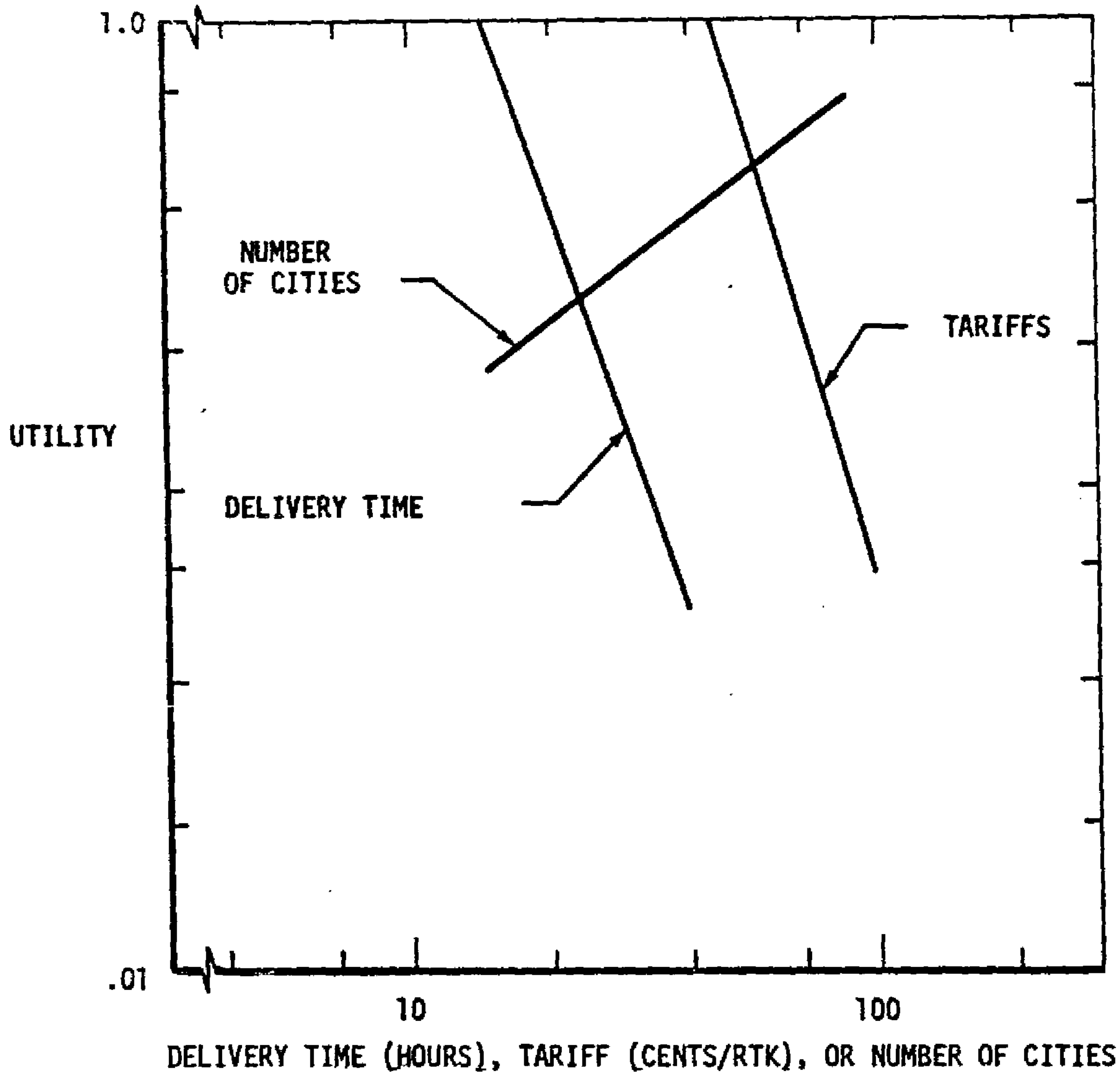

Figure 7-3. Relative Utility of Delivery Time, Tariff and Number of Cities

air decreases. The slopes are almost equal, i.e., a percentage decrease in delivery time is worth the same percentage price increase. The delivery time scales presented here are based on a shipping time from the "close of business," say 5:00 p.m. According to the plotted results, noon delivery, 19 hours later, is worth only 60 percent of 9:00 a.m. delivery 16 hours later in the same time zone. Truly, airfreight is a perishable commodity -13 percent per hour.

Delivery speed is a marketable commodity. At the margin, time and price are equally important. The findings certainly support the air cargo marketing philosophy that overnight delivery of airfreight is as a differentiated product. It seems clear that price and delivery time are equally important in the international market. How else can the rapid growth of international air cargo be explained in the face of the very large price differential?

Another measure of service through product differentiation is the number of destinations served. As the number of possible destinations increases, the utility of using air also increases. The shipper at one point in time is only interested in a single destination city. Consequently, the opportunity for using air as a general transportation mode should not have as steep a slope as would be expected for either time or price (Figure 7-3). A 50-percent change in the number of destinations is worth only a 12-percent price increase.

Future Market Rates

Until recently, the structure of the air cargo industry has been established and maintained by government regulations. This has operated to restrain entry into the air cargo industry and to maintain rates based upon costs. This protected an infant industry by guaranteeing, to some extent, the profits necessary to maintain growth and stability. This, in fact, has evolved into a legal oligopoly where more or less established fares and routes awards are the means for allocating the market among the member carriers. The impact of deregulation on this structure cannot be appreciated now. At the very least, it will undermine the structural stability of the industry.

An example of what might happen in the future is at hand. The traditional air cargo industry operators have made their costs and taken their prices in a manner compatible with the result of government regulations intended to guarantee profits. Totally different behavior would characterize an organization that takes its price and makes its cost so that profits can ensue. A case in point is Federal Express. Not only was Federal Express able to find a legal loophole to enter the industry, but by careful planning and system design they were able to make their costs so that at some business volume Federal Express would be a profitable organization. In the July 21, 1975, issue of Aviation Week in an article titled "A New Kind of Flight Plan for Small Freight" quoted a Federal Express salesman as saying, "We are 10 percent below air express". This differential was apparently necessary to launch a new enterprise in the face of existing air express service. The fact that they were able to do so and still bring the organization to the threshold of profitability indicates that they certainly were able to make their costs as opposed to merely taking them.

This pattern of new entry is suggested by theoretical economic considerations. Leftwich, Reference 7-3, treats the situation at some length.

"If entry into a currently oligopolistic industry is comparitively easy, it may not remain oligopolistic in the long run .... If the market is limited, the number of firms may still be small enough to make it necessary for each firm to take account of the actions of others. If so, the market situation remains one of oligopoly". If the market is so extensive that more firms can enter, the "market situation will have become one of either pure or monopolistic competition .... since entry into an industry tends to be the nemesis of colusive oligopoly, colusion usually can be maintained only when entry is restricted and it (oligopoly) has as one of its purposes the erection of barriers to potential entrants.... Among the artificial barriers to entry, those enforced or supported by the state loom large....... While oligopolists may be reluctant to encroach upon each other's market shares by lowering product price, they appear to have little hesitancy in using other means to accomplish the same results. Product differentiation offers a much more subtle and a safer way of accomplishing the same results. When quality and design variations are

used to increase individual firm market shares ... retaliation by the rivals will occur. Successful innovation will be imitated and improved upon. Individual firms may in succeeding increase their market shares temporarily; but if a permanent increase is to be obtained, such firms must be able to keep ahead of their rivals. Even when entering firms are taken into the cartel a strong presumption exists that disolution of the cartel will follow eventually.... A strong incentive now exists for individual firms to break away from cartel". Single firms face "a more elastic demand curve in the neighborhood of the cartel price than does the cartel". The breakaway firm "can make profits provided others remain in the cartel and the cartel price is maintained. The temptations facing each individual firm are likely to result in a breakup of the cartel". This treatment by Leftwich predicts the Federal Express scenario.

A differential pricing multitier tariff approach in fact has been adopted in the air cargo industry. A major question is, of course, whether or not it is been used effectively or efficiently to promote market growth; the industry evidence is not conclusive. Price differentiation has been practiced in many other transportation industries. It has been used extensively in rail, truck, and barge transportation. The results of MIT studies in price elasticity are very revealing. Some of these elasticities are presented in References 7-4 and 7-5 and summarized in Table 7-2. There are, for example, strong tendencies in all three industries to charge differential rates for mileage and even for some shipment sizes. In the latter case, rather than being given a price reduction the large shipper may be, in fact, be charged somewhat more. Commodity price differentiation provides discounts for very dense commodities, a slight price break to liquids, and gaseous commodities seem to be charged more. In part, this may reflect an increase in cost but in many cases reflects the relative difficulty of diverting these shipments to other modes. It is an opportunity, under the regulated structure, to enhance earnings when there are few alternative transportation modes. A differential pricing structure would be supported by relative inelasticity of demand, i.e., air cargo carriers would be better able to practice price differentiation than if demand were more price elastic.

The three econometric scenarios for domestic air cargo growth presented in Section 2 forecast industries may grow to constitute 0.5 to 1 percent of total domestic revenue tonne-kilometers in 1990. However, the realization of this growth will depend upon the price future elasticity of demand, and upon the industry's ability or willingness to cut prices. The latter will, in turn, depend upon the structure of the air cargo industry and the technologies that will be implemented in the interim.

TABLE 7-2

DIFFERENTIAL PRICING PATTERNS IN GROUND TRANPORTATION

	Rail			Truck			Barge	
	Official Territory	Car Load	Trailer on Flat Bed	Truck Load	Less Than Truck Load	Minimum	Rail Distance	Water Distance
Mileage Variables								
Mileage (Greater Than)	0.486	0.549	0.421	0.261	0.305	0.122	0.409	0.318
250 Miles				0.425			0.267	
300 Miles		0.152						
500 Miles			0.414		0.166			0.384
Weight Variables								
Weight (Greater Than)	-0.897	-0.767	-1.138	-0.823	-0.156	-0.978		
12 Tons			0.750					
15 Tons				0.791				
20 Tons	0.661	0.355						
60 Tons		0.305						
Value Variables								
Value	0.206	0.153	0.411	0.092	0.023		0.992	0.759
Value x 10^{-1}								
Commodity Variables								
Density			-0.026	-0.092	-0.169			
Particulate							-0.283	-0.271
Liquid			-0.109					
Gas	0.580	0.380						
Sample Size	121	494	461	191	301	92	200	200

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What will happen to the future structure of the air cargo industry is the question uppermost in the minds of those involved. Federal Express is a fairly successful version of a theoretical entry attempt. Entrepreneurs and/or enthusiasts will see the apparent opportunity for profit by providing service, catering to certain routes, and/or through hauling certain commodities. They will specialize in those routes and those commodities as suggested by Leftwich. Because they are specialized, they should be more efficient at performing limited differentiated services. At the same time, under deregulation, we should expect to see the marginally larger operators disappear either by merger or exit from the industry. Therefore, along the scale of air cargo industry member sizes, it is reasonable to expect to see a fair number of small new entrants on one end and on the other a few efficient large air cargo operators.

SECTION 8

OPERATING COSTS

During the past few years, all cargo unit direct operating costs as reported to the CAB have been decreasing by about 4 percent in constant dollars for every 10 percent increase in operating revenue. This has been the result of larger aircraft with constant crew size and lower unit fuel costs, sometimes at the expense of capital cost. Average indirect costs have been decreasing at a much faster rate. For every 10 percent increase in revenues there has been about an 8 percent decrease in unit indirect costs. This is caused by increases in the volume of operation, i.e., returns to scale. Very few personnel have to be added to the sales promotion and corporate staff to accommodate large increases in revenue tonnes. The smoothed results can clearly be seen in Figure 8-1 for direct operating cost and in Figure 8-2 for indirect operating cost. These graphs dramatically display the direct impact of the 1973 oil embargo upon direct operating cost and the concomitant spill-over effects in indirect operating cost. Both figures display the quantum behavior of average unit cost after the 1973 to 1974 impact.

The deviations from smoothed, calculated data are perhaps best shown by plotting the actual data of reference against the calculated data shown in Figures 8-1 and 8-2. The calculated data were provided by two simple regression models describing direct and indirect operating cost. The direct operating costs (DOC) model expressed cost per tonne-kilometer as a function of the tonne-kilometers of freight and express, three (not four, an elementary application of Walras' theorem) quantity dummy variables, and a dummy variable for the year. The latter was zero through the fourth quarter of 1973 and one thereafter. The indirect operating cost (IOC) model substituted tonnes for tonne-kilometers. The deviations between the actual and calculated DOC shown in Figure 8-3 is 10 percent for the 1971 to 1973 data. Although the 1974 to 1976 data are apparently not as closely grouped about the 45-degree line of perfect fit as the 1971 to 1973, individual

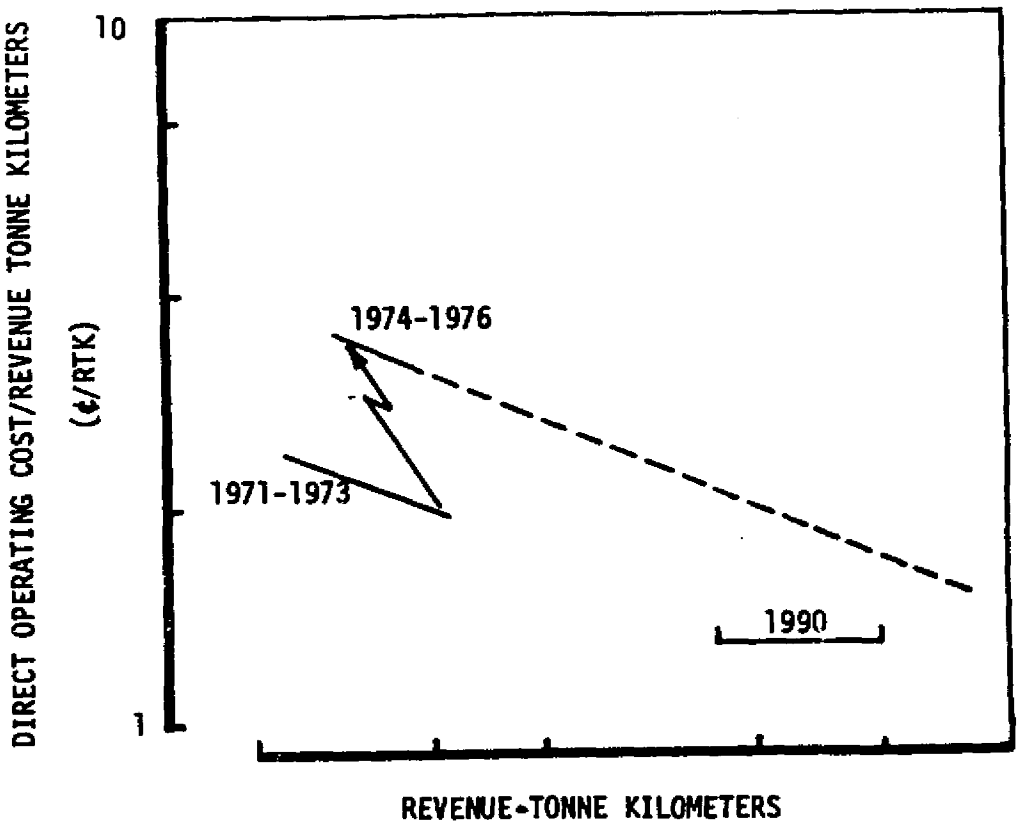

Figure 8-1. Direct Operating Cost
vs Revenue Tonne-Kilometers

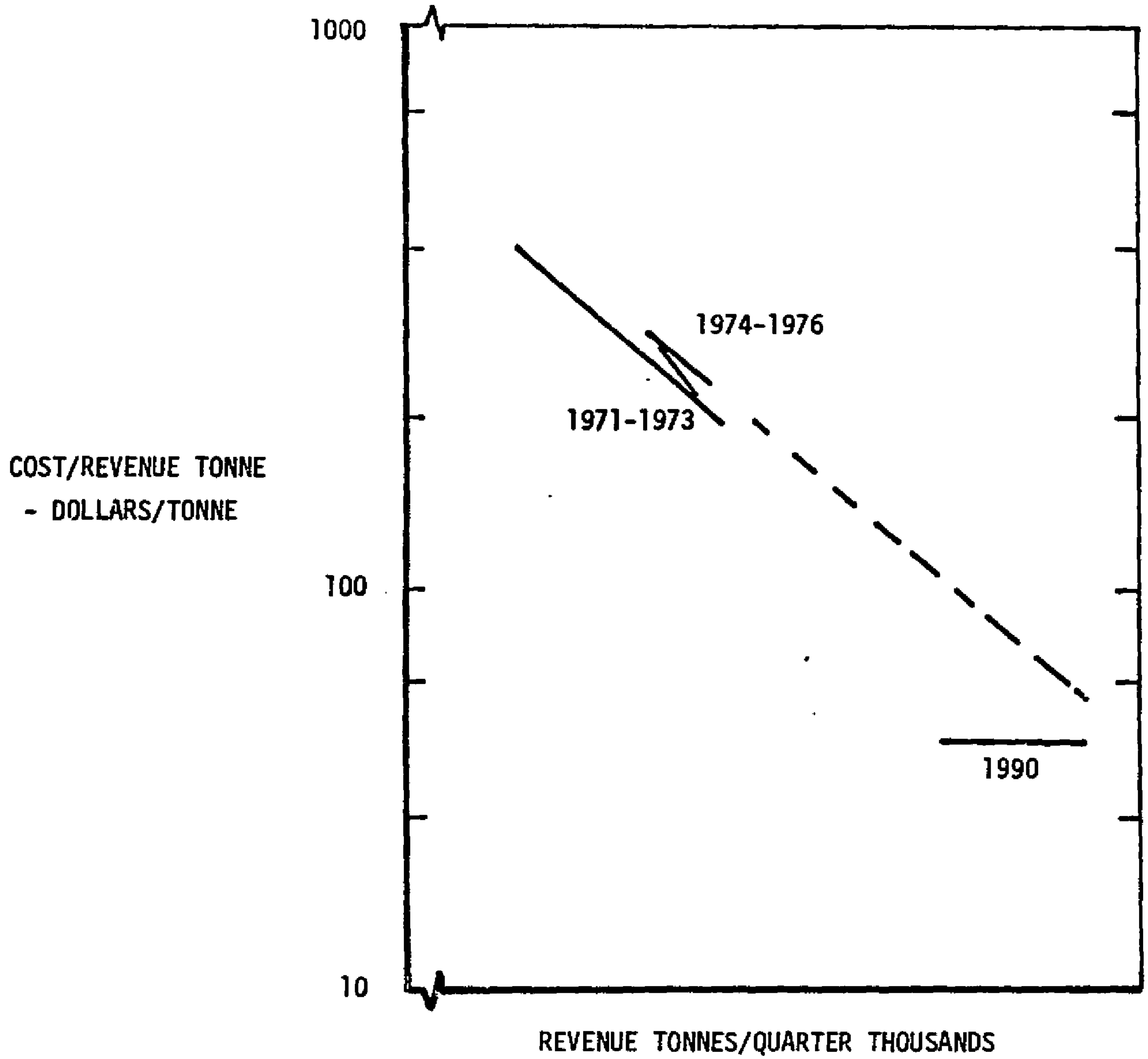

Figure 8-2. Indirect Operating Cost vs Revenue Tonne

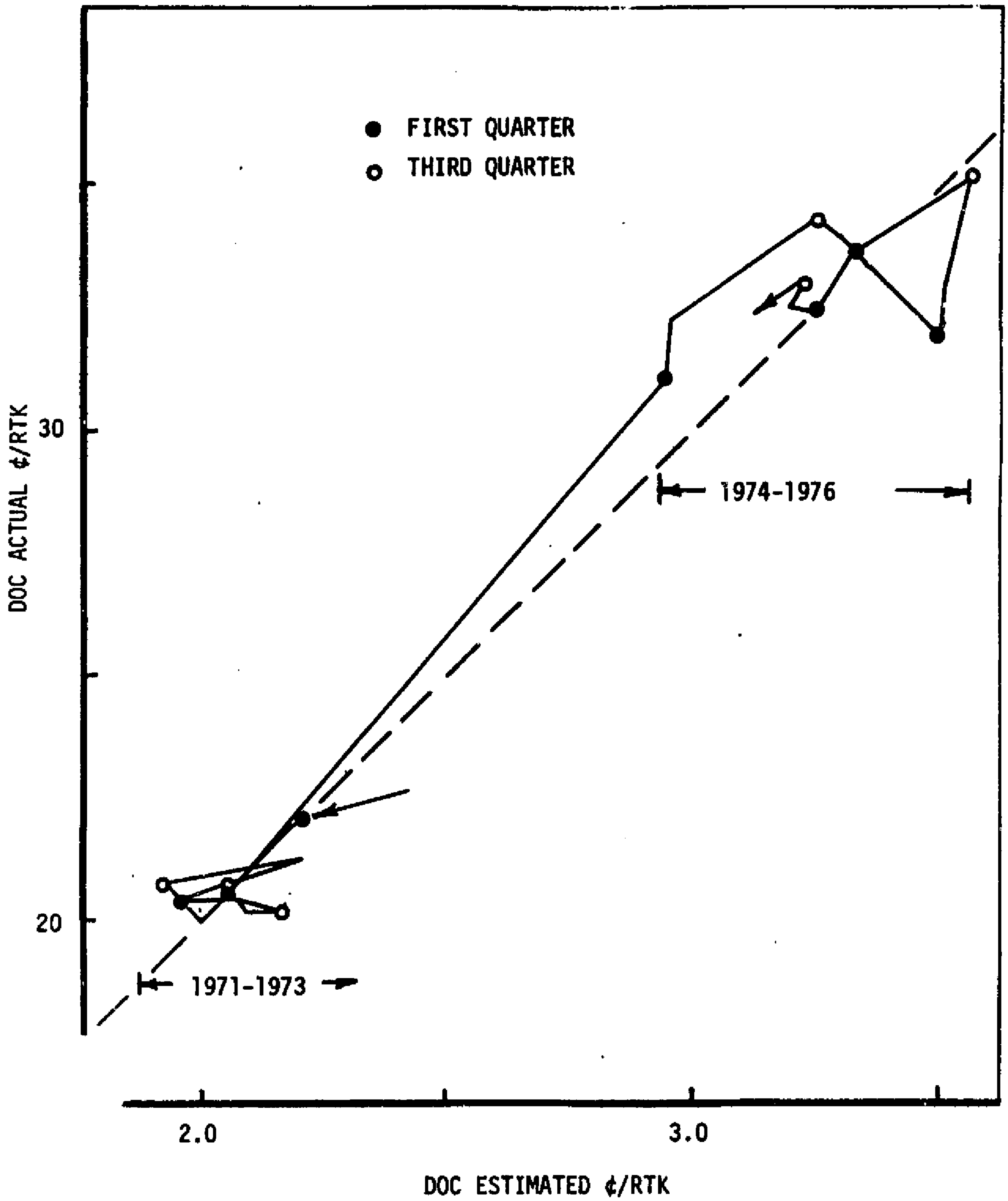

Figure 8-3. Actual vs Estimated Direct Operating Costs
1973 to 1976

deviations between the actual and the estimated data are less than 10 percent. This supports the use of a dummy variable to depict the impact of the 1973 oil boycott. The corresponding IOC plot, Figure 8-4, shows very small deviations between the actual and estimated data and clearly demonstrates the continuing downward trend of indirect operating cost despite the discontinuity introduced by the oil embargo and oil price increase.

There are many technological opportunities for improving the direct operating costs of future air cargo aircraft. Although currently it is fashionable to focus upon energy conservation, over the long run it is equally important to strive for continued improvements in aircraft structure for its own sake. The use of active controls, which now may be constrained by computer performance, has benefits for fuel conservation and for reducing the structural weight of future aircraft. The prices paid for these new technologies may be higher than current prices, but long-term direct operating cost benefits should accrue from advanced technology.

Technology can also affect the indirect operating cost. Advanced air traffic control systems not only will reduce holding pattern time with benefits for aircraft scheduling but will also reduce the indirect cost associated with management of the air cargo airline itself. Other indirect operating costs that may be susceptible to improvement by advanced technology include cargo handling and aircraft service. In a separate section of this report, the possibilities for improving cargo handling cost through advanced technology have been exhaustively examined.

Trunk and all-cargo operators incur the DOCs and IOCs, but the pattern is different. Table 8-1 displays the primary causal factors influencing major direct and indirect cost elements on the left followed by the direct, indirect, and total cost distributions of domestic trunk and all-cargo operators. The source for Table 8-1 was CAB Form 41, Trunk Carriers 2:00 Quarter 1976, and All-Cargo Carriers - Calendar 1976.

The causal factors have been classified into the resources expended, labor and material, administration reflecting the operating policies,

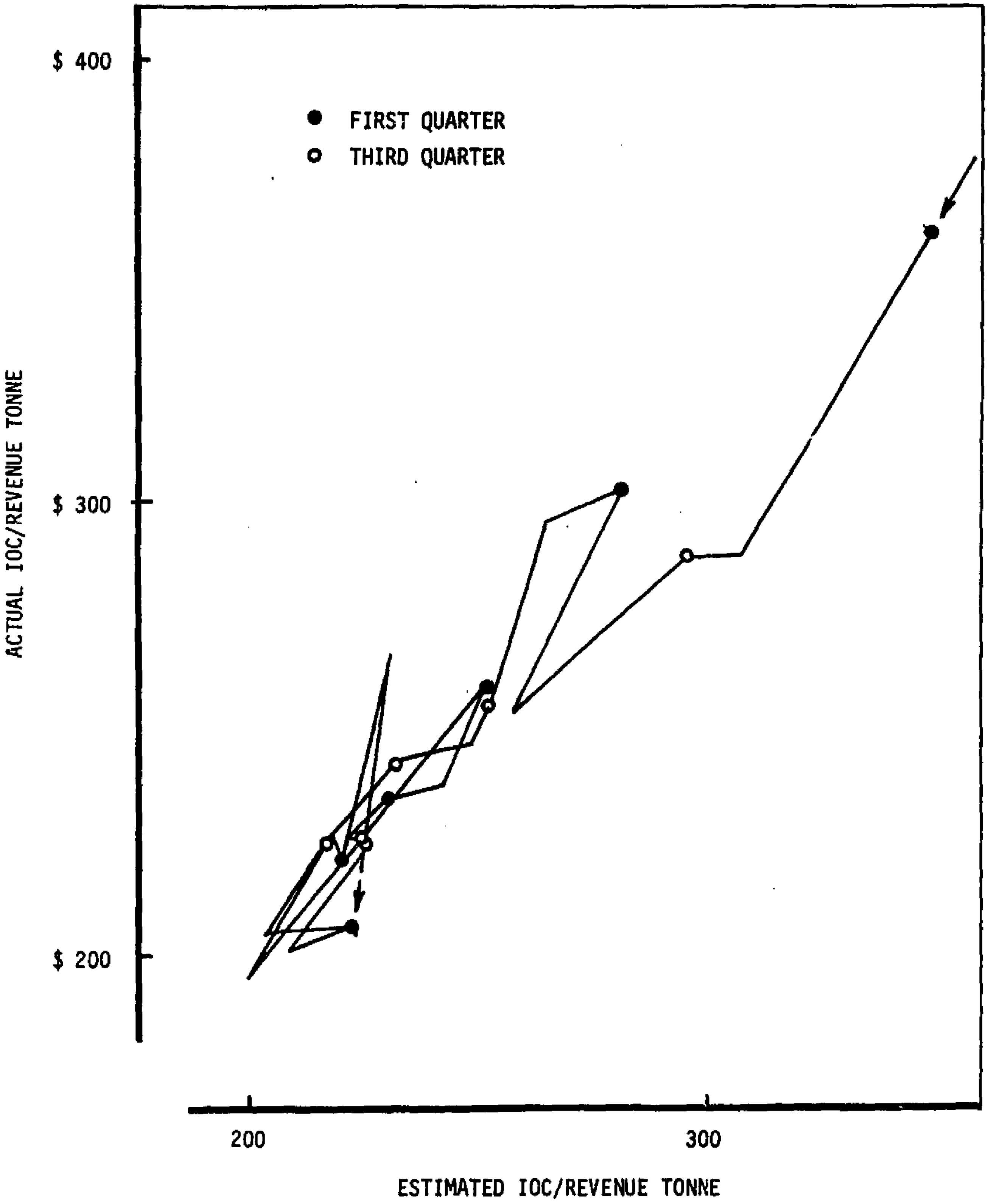

Figure 8-4. Actual vs Estimated Indirect Operating Costs
1971 - 1973

TABLE 8-1

CAUSAL FACTORS AND TRUNK AND ALL-CARGO CARRIERS COST DISTRIBUTIONS

	Causal Factor						Trunk Carriers			All-Cargo Carriers		
	Labor	Material	Admin	Aircraft A/C Design	Airport Terminal	Traffic	% DOC	% IOC	% TOC	% DOC	% IOC	% TOC
Flight Personnel	X			X			16.47	6.45	11.51	12.45	0.84	8.02
Maintenance Labor	X			X			5.53	1.60	3.58	3.35		2.07
Aircraft and Traffic Personnel	X				X	X		22.46	10.95	0.02	22.47	8.58
Trainees and Instructors	X		X				3.41	3.86	3.62	0.73	0.39	0.60
Other Personnel	X		X				4.74	7.38	6.06	4.20	17.58	9.31
Utilities		X			X		1.77	4.49	3.11	0.29	4.62	1.94
Commissions		X				X		7.26	3.60		7.49	2.86
Fees	X		X				0.01	0.28	0.15	0.01	1.43	0.55
Purchased Services	X		X				2.49	4.39	3.41	4.15	12.25	7.24
Landing Fees			X					4.26	2.11		8.27	3.16
Fuel and Oil		X		X			33.16		16.73	39.57		24.48
Maintenance Material		X		X			5.81	0.65	3.25	1.86		1.15
Rentals			X		X		6.66	3.41	5.05	11.83	4.86	9.17
Passenger Food	X					X		8.11	4.02		0.60	0.23
Other Purchases		X				X	0.69	0.76	0.78	0.36	2.98	1.36
Insurance			X			X	0.35	0.47	0.40	1.49	0.47	1.10
Benefits and Pensions	X		X				6.13	8.72	7.11	3.89	4.24	4.02

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TABLE 8-1. - Concluded

CAUSAL FACTORS AND TRUNK AND ALL-CARGO CARRIERS COST DISTRIBUTIONS

	Causal Factor						Trunk Carriers			All-Cargo Carriers		
	Labor	Material	Admin	Aircraft A/C Design	Airport Terminal	Traffic	% DOC	% IOC	% TOC	% DOC	% IOC	% TOC
Tariffs Timetables	X		X					0.23	0.11		0.09	0.03
Sales and Promotional Expenses	X		X					3.53	1.74		1.25	0.48
Taxes	X		X				2.25	3.86	3.36	1.40	4.25	2.49
Other			X				0.41	7.14	4.62	0.01	5.92	2.26
Airworthiness and OBSO.			X	X						7.89		4.89
Depreciation			X	X			10.12	2.77	6.48	6.50		4.02
Foreign Exchange (Items Deleted)			X					0.03	0.02			
Components in Percent							50.50	49.50	100.00	61.82	38.18	100.00

aircraft design that dictates capital as well as the labor and material resources, airport and terminal reflecting ground operations, and a traffic component. These classifications show most costs are incurred as a consequence of a complex coupling of at least two primary factors in addition to interactions with secondary factors. This part of the table points to the factors that should be examined to reduce given cost elements. For example, two factors should be addressed to reduce depreciation, administration (accounting and financial policies), and aircraft design. The airport/terminal column shows the costs are particularly sensitive to technology applied to the infrastructure, namely aircraft and traffic personnel. These are the points at which advanced technology might be applied to reduce the total cost of air cargo operations.

The overall cost incurred by the trunk carrier cargo operations probably closely correspond to comparable costs incurred by all-cargo operators but with considerable variation in distribution. When the detailed direct costs are examined, it is seen that the all-cargo carrier experiences relatively lower flight personnel costs, maintenance labor cost, benefits, and promotion. On the other hand, it experiences higher maintenance material cost, rental, and depreciation cost. The all-cargo carrier experiences little indirect cost for flight personnel, simply because the cabin personnel are not required for all-cargo operations. However, other personnel costs are higher as are outside services, landing fees, and taxes. These are offset by lower training cost, pensions and benefits, and miscellaneous costs.

The all-cargo operator experienced lower total operating costs for flight personnel, aircraft maintenance labor, training, other personnel, benefits and pensions, miscellaneous, and airworthiness operations costs; but other costs, such as personnel, fuel and oil, and rentals, are higher. Some of these differences have occurred because all-cargo operations are not burdened with the additional expense associated with servicing a human market. Some, are the result of a leaner and more directly responsive management structure.

Direct Operating Cost

Since air cargo direct operating costs are a function of the aircraft employed and are the dominant cost, new aircraft concepts are likely candidates to be examined in the search for lower total costs. This requires not only evaluation of the DOCs but also aircraft development strategies. There are three strategies for designing and purchasing all-cargo aircraft. The first is to procure a derivative of a commercial passenger aircraft. This option usually has been selected because passenger aircraft are optimized for cruise economies. The second is to procure cargo aircraft derived from military aircraft that could employ a joint commercial-military development and production program. The third, and one which has been employed only in isolated instances, is the development and production of aircraft optimized for commercial cargo operations. It is apparent that there are many design compromises inherent in the selection process accompanying the first two options and there are also design compromises entailed in the last option. The relatively small size of the all-cargo market combined with the distinctly different requirements perceived by the carriers serving those markets means that optimized all-cargo aircraft will have design compromises. The usual outcome of the first two choices suggest that a commercially derived all-cargo aircraft would have better drag and fuel consumption characteristics than an all-cargo aircraft derived from a military model. It is not nearly so clear that the unit price of an air cargo airplane derived from a passenger airplane would be greater than, equal to, or less than the cost of an airplane derived from a military air cargo airplane. Past commercial sales of airplanes derived from military aircraft have been disappointing, with air cargo operators consistently purchasing airplanes, and particularly larger aircraft, derived from passenger airplanes. Production runs of large military aircraft suitable for cargo have not, in the past, been large enough to reduce unit and prorated R&D cost low enough to overcome the historical military aircraft cruise inefficiencies. That is not to say that it will always be so. However the precise tradeoff depends upon a host of design details that transcend the mere commercial/military distinction.

One of the limiting details is pressurization, which has a significant impact upon design and performance. Military aircraft design has not been able to forgo pressurization because unit moves and paratroop capabilities are military doctrine. However, it is not yet clear that commercial all-cargo aircraft can forgo this requirement. Truck bed cargo floor height is almost a mandatory military requirement to permit forward area operations where unique loading equipment is not available. Commercial air cargo aircraft do not need truck-bed height. Drive-through loading is a military, not a commercial, requirement. The military requirement for reinforced flooring to transport heavy vehicles is usually unnecessary in the commercial market. The military has a requirement for large cross sections, whereas the commercial market requirement only needs to accommodate the largest container. The military has a 463-L pallet requirement, while commercial aircraft must be capable of carrying a large variety of ULDs. Military operations require significantly shorter field lengths than are required for commercial operations. In the past, the military has preferred high-wing and commercial low-wing designs; however, it is not clear that the drag performance of the high wing, per se, is an untenable penalty for commercial operations. Other design features proceeding from different requirements are noise suppression and high floatation landing systems.

Uncompromised cargo airplanes, although more efficient than derivative aircraft, have not been successful either. This is due to the fact that the past air cargo market has not been large enough to support long production runs of such specialized aircraft. Long production runs are essential to preserve the financial stability of manufacturers and the sales price. Past history does not mean that a solution cannot be found. On the contrary it suggests that the approach to designing compromise aircraft must be radically altered. The novel solution offered by one commercial transport manufacturer, e.g., an aircraft with a common fuselage and wing but with either a two- or a three-engine tail, may be an example of this kind of strategy. In the case of very large transport airplanes, even more radical variants can be considered.

The answers to passenger, military, cargo aircraft compromises do not rest with the individual examination of design features and penalties.

Figure 8-5 depicts the change in airplane weight associated with a change in aircraft performance for some 35 individual variations from a military transport baseline design. These variations encompass changes in the design features listed in Figure 8-5. The weight/performance relationship of most of these variations lie in a very narrow band tilted about the origin. The thinness of the band is indicated by the expanded scale of the axes. Only two features drive the weight penalty and, therefore, the cost penalties/ outside this narrow band: noise reduction (ΔEPNDB) and very short runway lengths. Therefore, it is not the inclusion of a single feature that makes the compromise aircraft problem acute; it is, rather, the accumulative effect. This compounds the problem of compromise designs for multirole large transport aircraft.

Comparisons of advanced technology and current technology aircraft were undertaken to indicate the possible benefits of advanced technology. The results of casual comparisons are not persuasive since some of the relative benefits may have been masked under design and/or production differences. For example, the B747-200F was compared with an advanced technology military/ commercial aircraft. Both airplanes have the same design payload and approximately the same cruise speed. The empty weights were almost identical as were the takeoff gross weights; however, the design ranges were different 4630 versus 6667 kilometers. Another important factor is the market size implicit in the current B747-200F price and the projected market for an advanced military/commercial airplane. The relative operational cost of these two aircraft are illustrated in Figure 8-6 in terms of the ratio of their respective trip costs. While the advanced aircraft shows a fuel consumption improvement, around 4 percent, the trip cost is 10 percent greater due to the increased cost of depreciation. The relative fuel price line, constant aircraft unit price, shows the relative importance of improved fuel consumptions as fuel prices vary from 50 percent to 4 times current levels. However, even with fuel prices quadrupled, the advanced military commercial airplane would not be competitive with the presently in-service B747-200F if aircraft markets were limited to 200 units. A larger market, 384 aircraft, would reduce the direct operating costs (with fuel cost held constant) of the advanced aircraft to those of the B747 at a 4500-kilometer stage length.

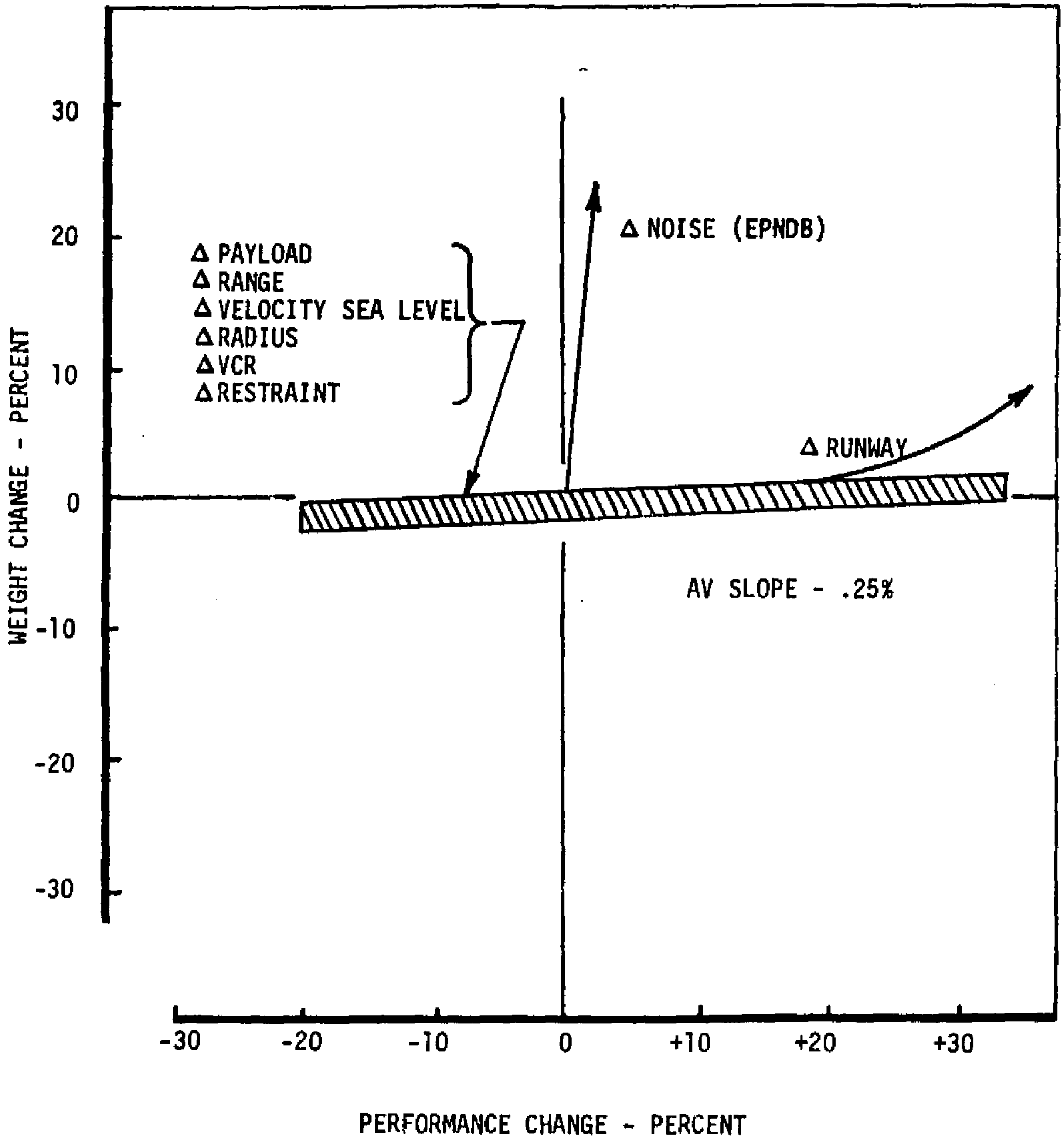

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Figure 8-5. Cost Weight Penalty/Benefit
vs Performance Parameter Penalty/Benefit

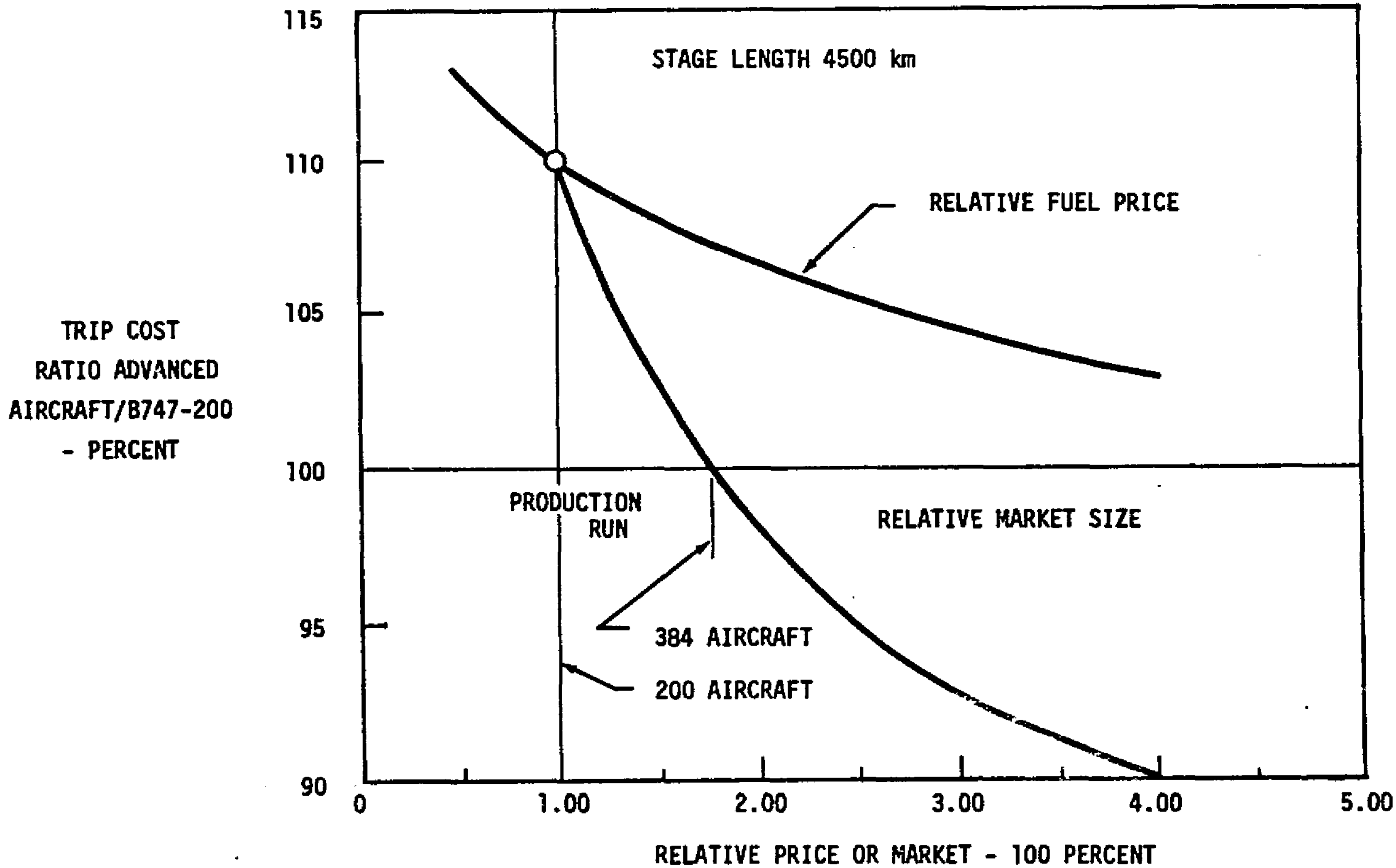

Figure 8-6. Relative Trip Cost vs Relative Fuel Price and Advanced Aircraft Market Size

A discussion of the system performance of these and other derivative and advanced technology aircraft may be found in Section 11.

Indirect Operating Cost

The productivity of cargo handling manpower was examined using CAB Form 41 data. Figure 8-7 shows the actual productivity per quarter for the last 6 years. Cargo handling productivity for all-cargo carriers has been increasing at a rate of about 6 to 7 percent per annum on a compounded basis. Cargo handling productivity for trunk carriers has changed very little. The latter data are heavily influenced by the larger passenger baggage handling task, which is reported in the same manpower category. Consequently, the higher all-cargo productivity gain, 6 to 7 percent per annum, has been used. The productivity model fitted to the data was:

$$\ln \text{Productivity}_t = \exp\left[-19.68 + K_t Q_t + 10.72 \ln (T-1958)\right]$$

Productivity = Quarterly Tonnes/Man

t = Time Period

Q_t = Quarter Number

K_t Nondimensional Index = 0.982 Qt = 1
0.000 Qt = 2
0.135 Qt = 3
1.306 Qt = 4

T = Year

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When normalized as shown in Figure 8-7, the calculated compound slope is 7.3 percent per anum. The actual model shows the slope flattens during the latter part of the 6 year period resulting in currently estimated slope of 6 to 7 percent per annum. Figure 8-8 shows cargo handling salaries have run between 40 and 50 percent of total air cargo IOCs over the same 6 year

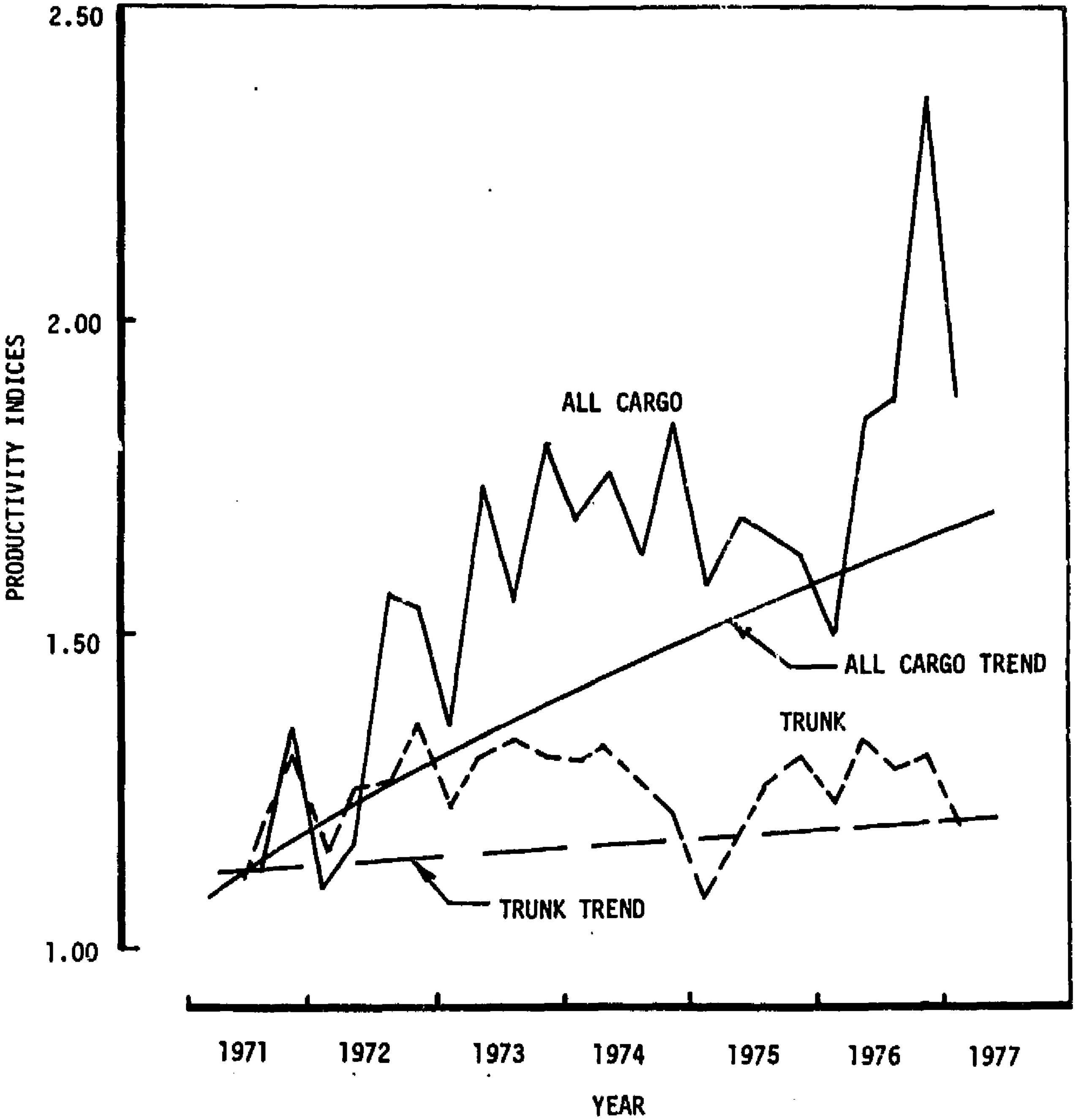

Figure 8-7. Productivity Indices for All-Cargo and Trunk Operations

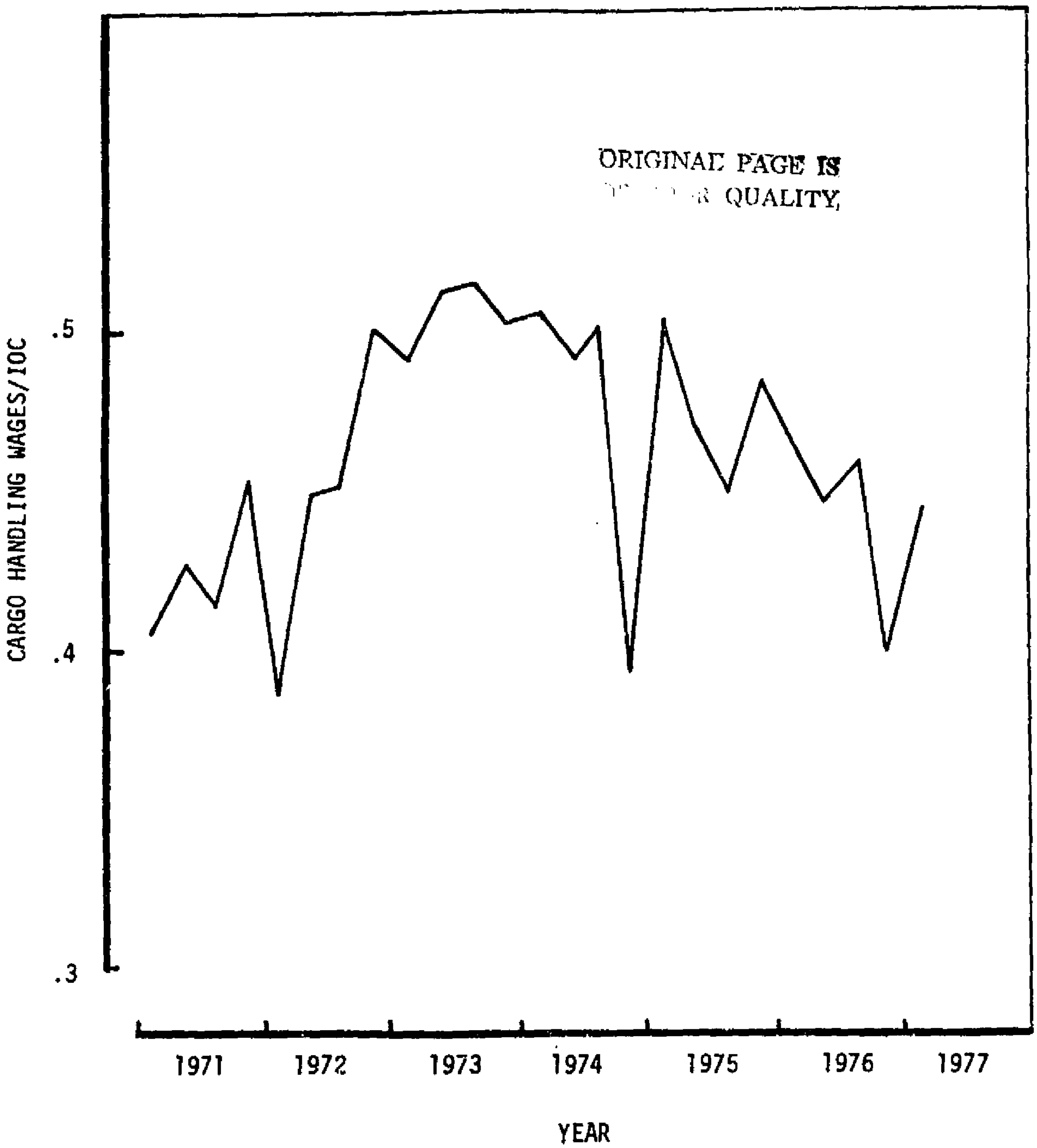

Figure 8-8. All-Cargo Airlines Wages
as Percent of Indirect Operating Costs

C-3

period. A model was fitted to estimate IOCs strictly as a function of cargo handling costs:

$$\ln IOC_t = \exp [5.75 + K_t Q_t + 0.62 \ln (T-1958) + 0.29 \ln W_t]$$

where IOC = IOC in total dollars per quarter (deflated)

Q_t = Quarter number

K_t = 0.000 Qt = 1

Nondemensional Index 0.013 Qt = 2

0.059 Qt = 3

0.128 Qt = 4

T = Year

W = Cargo handling wages in quarter (deflated)

The model quarterly results are compared to the actual IOCs in Figure 8-9 showing cargo handling salaries and/or cargo handling personnel can be used to make very accurate estimates of total cargo IOCs.

The historically close correlation of cargo handling costs and total IOCs supported the decision to closely analyze cargo handling costs. The results of that analysis are reported in Section 3. There are three relevant principal findings of the terminal studies. First, there is little chance of expanding current air terminals. Second, it is essential to transition to approximately a 90 percent shipper-packed container system. Third, after the transition to the 90 percent shipper-packed container system, intensive automation would result in smaller decreases in cargo handling costs. The conclusion that it will be necessary to transition to a shipper-packed container system dictates that the historical 6 to 7 percent per annum productivity growth rate can not be used to project future IOCs because this would introduce a discontinuous element instead of an evolutionary process.

As an alternate, the terminal data of Section 3 terminal analyses were translated into terminal manpower requirements as shown in Figure 8-10. These data relate manpower to terminal throughput tonnes and show varying peak conditions and terminal crew sizes. The lower left-hand corner shows the

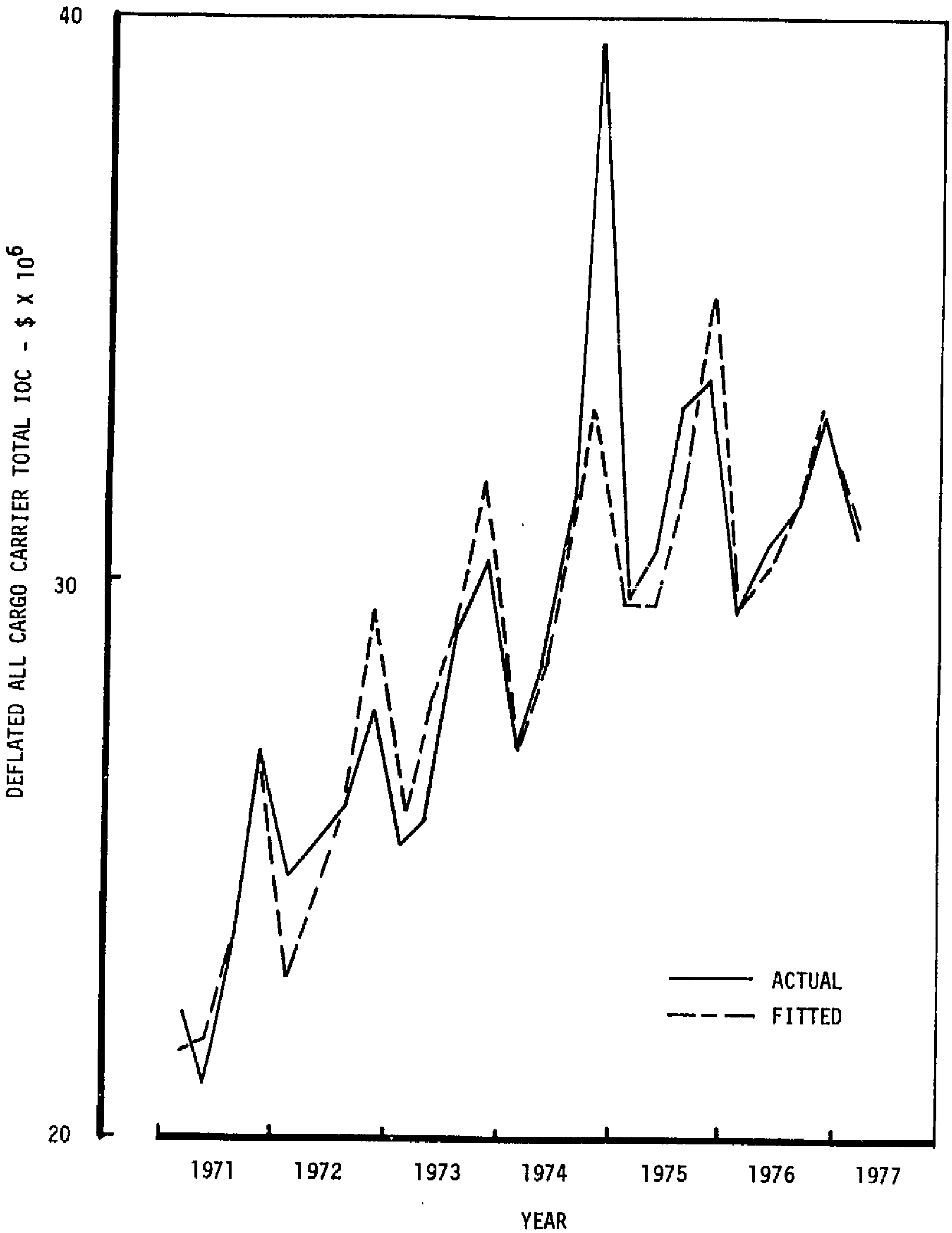

Figure 8-9. Goodness of Fit Indirect Operating Costs Model

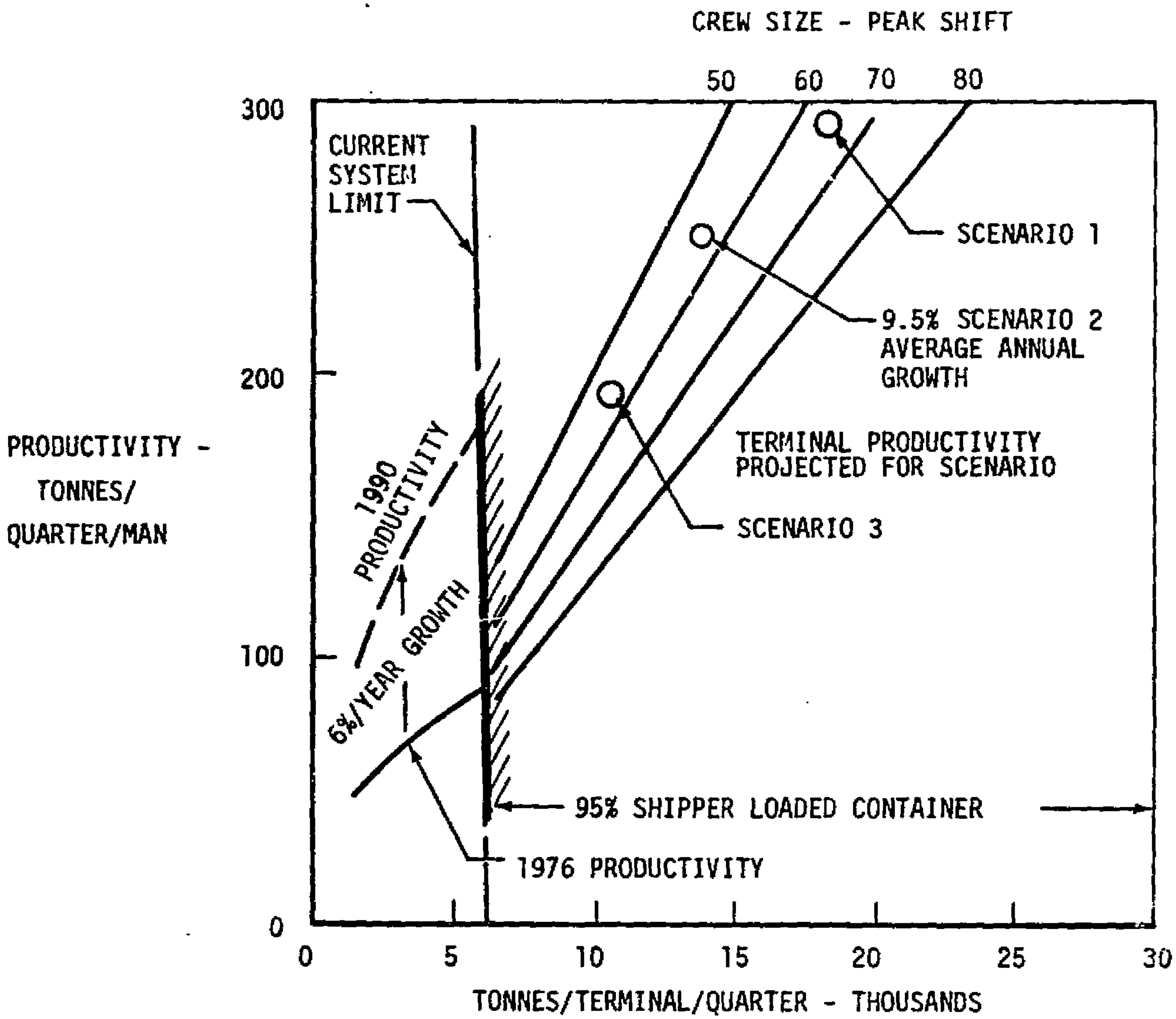

Figure 8-10. Productivity vs Tonnes

1971-1977 productivity growth trends of 6 percent per year projected to 1990 and the maximum terminal capability with the existing nonshipper-packed container system. On-site air cargo terminal capacity will limit the 1990-2000 flow to around about 6000 tonnes per terminal per quarter as discussed in Section 3. The three econometric scenarios presented in Section 2 and airport survey results postulate terminal throughput capacity requirements on the order of 10 to 20 thousand tonnes per terminal per quarter depending on the econometric scenario and terminal configuration (Section 3). These are shown by the open dots in the upper center of the Figure 8-10. Across the figure are lines of constant peak crew sizes for 50, 60, 70, and 80 men. This shows terminal crews to support the throughput capacity required by the 1990-2000 scenarios would not be significantly larger than today's terminal crews confirming the projections of Section 3.

Persistent daily fluctuations in peak loads are compensated by varying the crew sizes for each shift. The IOC model results presented earlier show annual, cyclic, and secular long-term changes. An analysis was made into the industry's ability to adapt terminal resources to cyclic and secular changes, borrowing a control theory concept-hysteresis. Applying this concept to the CAB cargo handling personnel and throughput data provides an indication of dynamic response. Two plots were developed: an all-cargo handling personnel versus tonnes per quarter including both freight and express and a trunk airline traffic handling personnel versus tonnes per quarter. The results, Figure 8-11, show the all-cargo carriers have been better able to adapt to both cyclic and secular traffic variations than have the trunk carriers. In fact, the all-cargo carriers have done surprisingly well. The only one minor deviation in the 1971 to the 1976 time period occurred in the last quarter of 1976. The corresponding trunk data display a much more scattered pattern. There is a pronounced hysteresis loop during the 1974 and 1975 time period (see the hatched track) beginning during the second quarter of 1974, which experienced a sharp increase in both tonnes and traffic personnel, and continuing into the last two quarters of 1975, through 1975, and into the last quarter of 1976. Other evidence, including relatively lower all-cargo pension costs and the sheer size difference suggest the trunk carriers being larger and more unionized are less able to respond to changing economic circumstances by changing the work force.

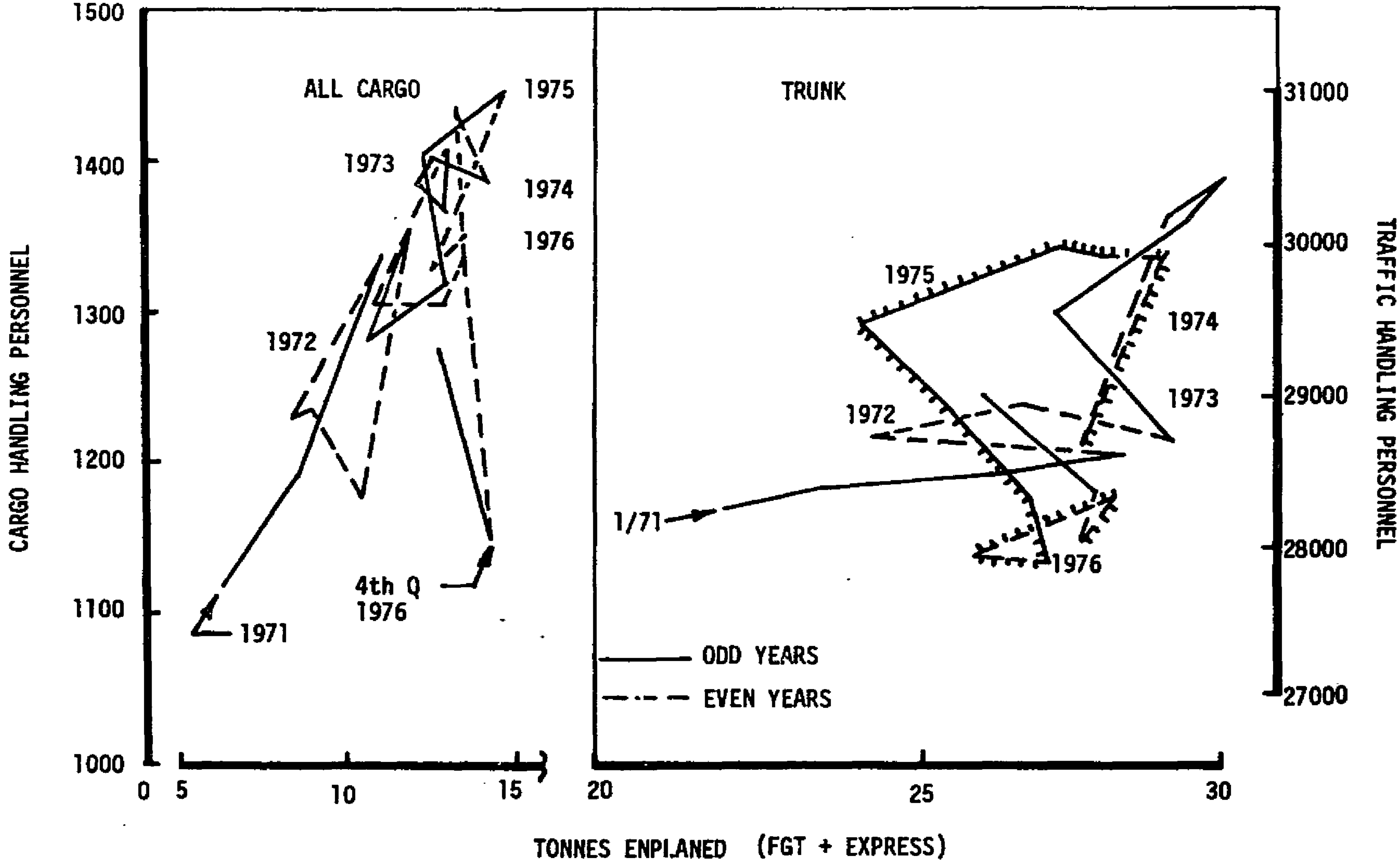

Figure 8-11. Hysteresis Plot-Traffic Handling Personnel
vs Tonnes Enplaned per Quarter

SECTION 9

OPERATING PROFIT, RATE MAKING, AND RETURNS

Having described the market aspects of the air cargo industry and the direct and indirect cost structures, it is possible to integrate these elements. The cost breakdown, Table 9-1, presented earlier, and the domestic airfreight rate investigation (DAFRI) rate formula discussed in Volume I, Section 1, provide the insight to assemble the direct/indirect operating cost elements into categories such that estimates of short-run and long-run costs can be made. Weighted average terminal and other indirect operating costs were calculated using DAFRI rate structures, updated to 1977, and 1976 domestic container flows of Section 3. This provided the physical characteristics of an average shipment, 49 pieces weighing 1000 kilograms over a distance of 4500 kilometers.

The various direct operating costs (DOC) and indirect operating costs (IOC) categories were associated with "by product" and "joint cost" costing approaches for combination carriers and short-run and long-run costs for all-cargo carriers as shown in Table 9-1. (By product costing assigns as a cost of a particular product or service only the cash or out of pocket expenses of producing the product or service. Joint costing allocates some or all of the common costs among the products or services.) Three categories of cost are shown in Table 9-1, variable, semivariable, and fixed. The variable costs are taken as those costs that are incurred in accepting the marginal, i.e., the last shipment put onboard an aircraft. The semivariable costs are taken as those costs that would be a function of adding a flight. The fixed costs are taken as those costs that cannot be altered over the short run. The combination carrier is representative of operators who accept freight in addition to passenger traffic, while the all-cargo operator utilizes both main deck and the belly for cargo only. The table identifies the percentage of DOCs and IOCs that go into the three cost categories. These cost distributions were then used to develop estimates of current costs of transporting the representative shipment of 1000 kilograms over a distance of 4500 kilometers under various assumptions.

TABLE 9-1

COST ELEMENT CLASSIFICATIONS

Cost Category	Combination Carriers				All Cargo Carriers			
	DOC %		IOC %		DOC %		IOC %	
	By-Product	Joint	By-Product	Joint	Short Run	Long Run	Short Run	Long Run
Variable Cost								
Fuel	33.16	33.16			39.57	39.57		
Terminal			22.46*	22.46			22.47	22.47
Commissions			7.26*	7.26			7.49	7.49
Subtotal	33.16	33.16	29.72	29.72	39.57	39.57	29.96	29.96
Semi-Variable Costs								
Crews		11.51				12.45		
Maintenance Labor, Mat'l Service		13.83		6.60		9.36		12.25
Landing Fees				4.26				8.27
Pensions & Benefits		6.13		8.72		3.89		4.24
		31.47		14.58		25.70		24.76
Fixed Costs								
Rentals, Dep. OBS		16.78		6.18		26.22		4.86
Passenger Food				8.11				0.60
Other Purchases		0.69		0.71		0.36		2.98
Insurance		0.35		0.47		1.49		0.47
Sales & Promotion				3.53				1.25
Taxes		2.25		3.86		1.40		4.25
Other Personnel, etc.		8.74		17.71		4.93		18.81
Utilities & Other		6.74		15.13		0.33		12.06
		35.37		55.70		35.73		45.28
TOTAL		100.00		100.00		100.00		100.00

The concept of a representative shipment, over the weighted average range of both domestic and international cargo operations, provides a way to illustrate (as in Table 9-2), the interaction of costs, technology, and elasticity in rate setting to determine profit for the air cargo operator, Table 9-2. The left-hand column of Table 9-2 presents the cost elements or categories that make up the total operating cost of an all-cargo operator. In this context, the all-cargo operator is also representative of the all-cargo operations of trunk carriers. The second column of the table depicts current operations, i.e., the average cost of transporting the 49-piece shipment of 1000 kilograms over 4500 kilometers. The next group of three columns represent lower-limit tariffs for belly-pit service, i.e., cargo on a passenger flight under short- and long-run conditions. The last group of three columns represent the minimum tariffs for all-cargo service under short- and long-run conditions. The first three cost elements of Table 9-2 plus depreciation and insurance represent the elements of the DAFRI capacity costs. The remainder, excluding general and administration, represent elements of DAFRI terminal costs.

The combination carrier might always exclude flight crew costs and flying operations, because they would be borne by the primary product, passengers. However, the all-cargo carrier must at least consider flight crew costs over the long run, even though for very short-term "spot" rates they might not take crew costs into consideration. The combination carrier might consider allocating only the additional fuel used by the 1000 kilogram shipment as short-run cost. However, over the longer run, the combination carrier would have to include more fuel to account for cargo compartment weights, although this allocation might still be less than a "true" weight allocation. The all-cargo operator on the contrary would have higher fuel cost allocations to the shipment over both the short and long run. The same rationale, in general, applies to maintenance. Over the short run, only some small fraction of maintenance costs might be allocated, while over a longer run more average maintenance costs must be covered in the tariff. The aircraft service category, fueling and turning the airplane around, may not be allocated at all in the combination case or under the very short-run all-cargo case; but full costs would have to be borne under the all-cargo long-run cases. The traffic service costs, including cargo handling and airplane loading personnel, could

TABLE 9-2

COMPARISON OF CURRENT, BELLY PIT, AND ALL-CARGO
AIRFREIGHT CHARGES FOR VARIOUS PRICING CRITERIA
SHOWING COST BREAKDOWN - 1976 SYSTEM

(NOMINAL SHIPMENT - GENERAL FREIGHT, 49 PIECES, 1000 KG, 4500 KM)

Cost Elements		Current Belly Pit Service			Current All-Cargo Service		
Expense/Revenue Categories	Current Operating Conditions	Short Run Minimum	Long Run Minimum	DAFRI	Short Run Minimum	Long Run Minimum	DAFRI
Flying Ops (W/O Fuel)	$ 55	$ -	$ -	$ -	$ -	$ 55	$ 55
Fuel	140	25	85	85	40	140	140
Maintenance	70	10	70	70	10	70	70
Aircraft Service	45	-	-	-	-	45	45
Traffic Service	115	50	115	115	50	115	115
Sales Promotion	40	0	20*	20*	-	40	40
Commissions	25	25	25	25	25	25	25
General Administration	40	-	20*	20*	-	40	40
Depr + Rental	160	-	10**	10**	-	160	160
Total Cost	$690	$110	$345	$345	$125	$690	$690
Operating Profit	25	-	5	35	-	85	110
Price	$715	$110	$350	$380	$125	$775	$110
% Current	100	15	49	53	17	108	119

* Assumed 50%

**Assumed 5%

cover only marginal costs over the short run with full costs covered in the long run. The combination carrier might allocate only a portion of sales promotion while the all-cargo carrier would have to allocate 100 percent to the long-run tariff basis. Both operators might ignore sales promotion costs in "spot" tariff making. Commissions, to the extent they are paid, are a marginal cost and are recovered in every case. The combination carrier might reduce cost recovery of general administrative (G&A) expense for long-run cost structures. Both combination and all-cargo carriers might ignore G&A for spot rate making. The same general considerations apply to depreciation and rentals. The combination carrier could conceivably charge much less than the all-cargo carrier under every particular assumption, resulting in a large range of potential tariffs. The exact tariff depends upon how costs are perceived and the primary business of the operator.

The DAFRI columns of Table 9-2 are calculated such that the costs are equal to the costs in the second column for each generic operator. The difference is the profit objective under the CAB rate of return policy, DAFRI, and the long-run minimum cost of money, roughly 8.5 percent during recent years. The latter excludes that increment of profit necessary for continued growth. The final line of the chart depicts the prices that might be charged under these assumptions, going from a low of $110 to a high of $800 for the same shipment. At current rates, the charge would be approximately $715. Thus, a factor in excess of 6 might describe the range of "rational" tariffs. The cost criteria used in constructing all the tariffs are the minimum the operator would be willing to accept under varying assumptions. Any price charged above those amounts would contribute to the operator's gross profit.

This simplified analysis concentrates upon the role of rate making and cost without becoming involved in the complexity of taxation and financing. Therefore, the focus is on operating profit, i.e., revenues minus air cargo operations in relation to operating assets (ROA) instead of on the more precise measure return on investment (ROI) which is frequently used. These two measures of operating efficiency can be related in the steady-state conditions

where the dynamic aspects used to calculated ROI no longer are important. ROI can then be related to return on assets (ROA) by the following transformation·

$$ROI = \frac{[ROA - i\ (1-c)]\ (1-t)}{c}$$

ROA	=	Return on operating assets
ROI	=	Return on investment
i	=	Interest rate
c	=	Capital ratio - equity/operating assets
t	=	Tax rate

The transformation, itself, is exclusively concerned with the taxation and financing aspects of corporate operations. The transformation further shows that as ROA increases ROI also increases. When the transformation is differentiated using a LaGrange multiplier, the optimal profit maximazation capital ratio can easily be developed. When ROA is less than the interest rate i, the optimal capital ratio is 100 percent. When ROA is exactly equal to the interest rate, there is no determinate solution for the equity-to-total operating asset ratio as illustrated in Figure 9-1. When ROA is greater than the interest rate, the optimal capital structure is as small an equity position as can be achieved. This is constrained only by permissiveness of lenders.

Utilizing the ROA concept, the interaction of the elasticity demand, the cost structure, and the return on operating assets can be examined. Table 9-2 suggests an estimate of all-cargo short-run cost slightly in excess of 18 percent (125/690) of average, long-run cost. Two additional normalizing factors were required. One to normalize the return of assets to the 76 results (1.1) and another factor (1.036) to relate revenue to cost in terms of the dimensionless parameters used in the simplified ROA equation:

$$ROA = 1.1 \left[1.036 \left\{ Y/Y_0 \quad (1 + \Delta G + \varepsilon \Delta Y/Y_0 \right\} - \left\{ 1.0 + 0.18 \quad (\Delta G + \varepsilon \Delta Y/Y_0 \right\} \right]$$

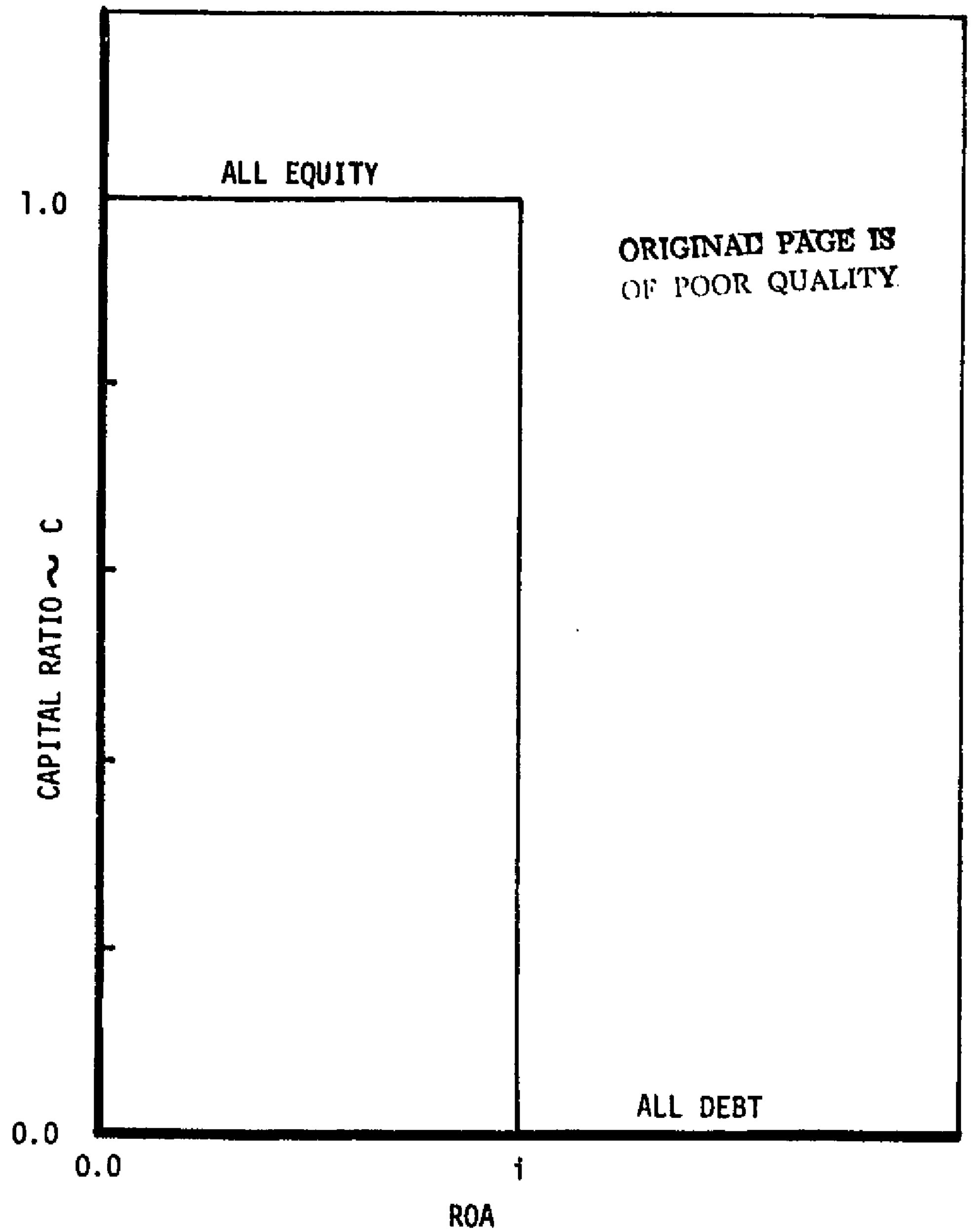

Figure 9-1. Optimal Capital Structure

where

Y_0 = Reference yield

ΔY = Change in yield (tariff)

ΔG = Annual external growth - percent

ε = Price elasticity of demand ≤ 0

The equation uses two terms, the first being the revenue term and the second the cost term. The revenue term is normalized by the revenue in the base period, 1976, and is dimensionless as is the growth term and the elasticity term. The cost term exhibits the same general structure.

Figure 9-2 shows ROA as a function of tariffs and external growth taken as increased load factor for the short-run case based on 1976 operations. ROAs are calculated for elasticities of (a) 0, (b) -0.65, (c) -1.275, and (d) -2. When elasticity is 0, Figure 9-2(a) shows that as growth factor and tariff increases ROA increase. This occurs because increases in tariff do not impact the physical market, i.e., the tariff and the market are decoupled. If, however, the model allows interaction between the tariff and the market (elasticity <0), the picture changes as shown by Figure 9-2(b), (c), and (d). In these cases, as the tariff increases the carpet becomes humped and the market begins to decrease at the higher tariffs with a resulting decrease in ROA.

External demand increases occasioned by growth of GNP, discussed in Sections 2 and 7, increases ROA. As the elasticity increases to -1.275 (Figure 9-2(c)), the carpet develops a pronounced roll and the 0 change tariff line is approximately optimal with any increase or decrease in tariff resulting in decrease ROA. Typical cases are shown by the three econometric scenario points of Section 2 located near the external 10 percent growth factor line. Here the 0 tariff change is clearly almost exactly optimal. It tends to maximize return on assets (ROA) and, therefore, return on investment (ROI) in the steady state. This theoretical analysis tends to emphasize price stability within the industry at least over the past regulatory posture. When, however, elasticity is increased to -2 (Figure 9-2(d)), the optimal short-run policy is to reduce tariffs rather than to increase them. Here the

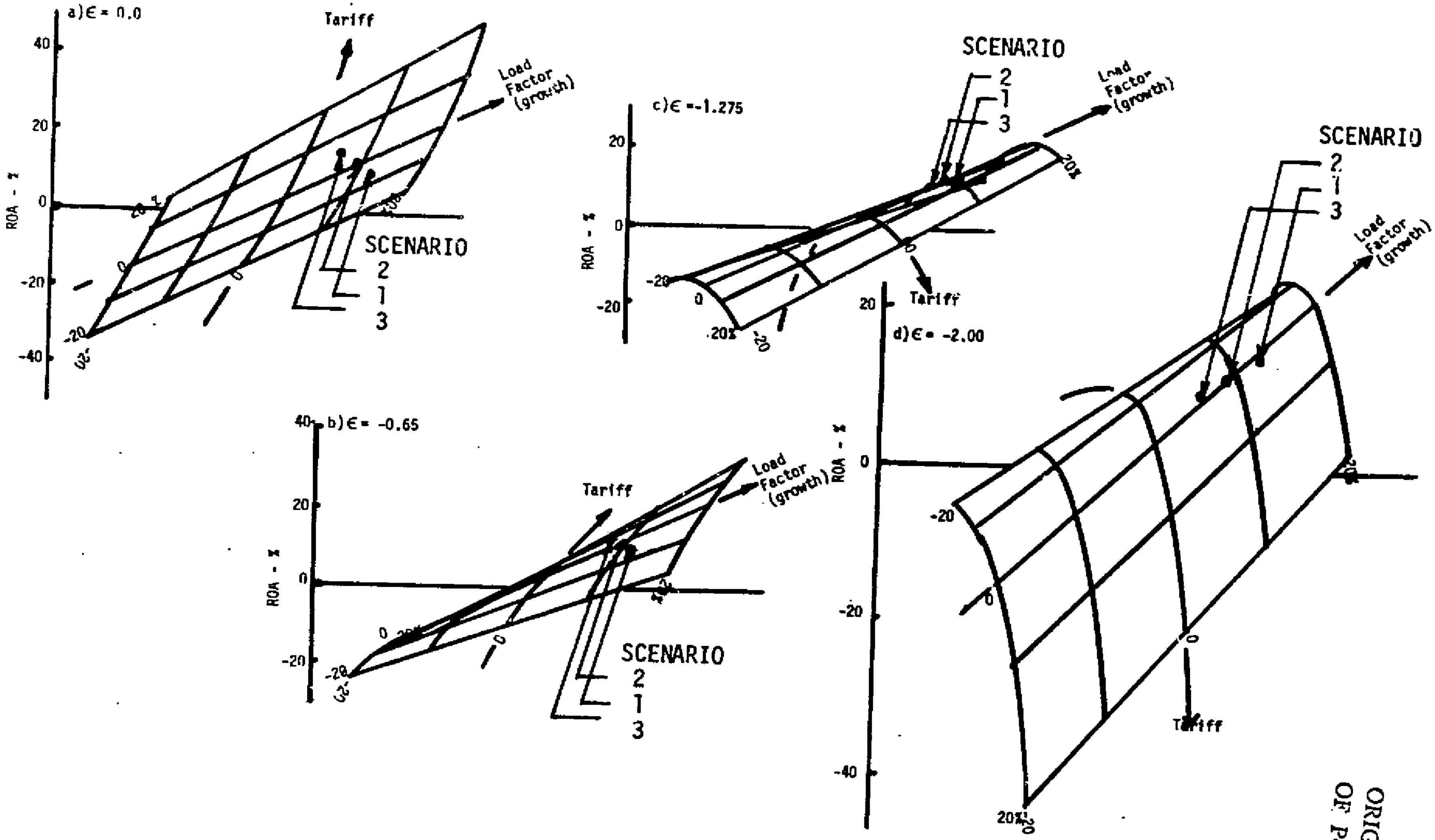

Figure 9-2. ROA as a Function of Tariffs and Load Factor, 1976 Operations
Short Run With Elasticities of 0, -0.65, and -1.275

approximately optimal short-run tariff strategy posture is to reduce the tariff by about 15 percent for the external growth factors of the A, B, and C econometric scenarios.

The results of these four carpet plots are now generalized into Figure 9-3. The plot utilizes the 9.5 percent-per-annum external growth, baseline scenario 2 of Section 2, and corporate tax rates of 48 and 44 percent for the ROA/ROI transformation presented earlier. The particular conditions shown are representative of the current all-cargo capital market, namely an equity ratio of 45 percent and an interest rate of 8.5 percent as obtained from CAB data. This shows that for price elasticities less than -1.33, i.e., the current situation, rate increases would be favored over rate decreases. There has been little evidence of aggressive tariff reductions to increase the air cargo market. The central role of perceived elasticity in determining rate-making behavior is clearly shown in Figure 9-3. The elasticity region suggested by the econometric analyses of Table 7-1 inherently leads to tariff (price) stability. The individual members of the air cargo industry perceive elasticities less than 1, for example, Reference 9-1. Under these conditions, there is no temptation to reduce prices; on the contrary, there is a tendency to increase prices to maximize profits to provide for adequate returns or further growth. Figure 9-3 also shows the relationship between ROA and steady-state, average, ROI. The policy of maximizing ROA also maximizes ROI since any increase in ROA also implies an increase in steady-state ROI. The only difference produced by different tax rates is the value of the ROI.

The following features regarding the economics of the past and present air cargo industry were derived by qualitatively combining the preceding analysis results with industry observations. By defining the present state of being, they represent the starting point for future growth trends.

- There is a significant external growth factor that results from increased real growth national product, GNP.
- The perceived price elasticities of demand are less than required to induce tariff reductions as a means of stimulating market growth.
- Economies of scale in short-run direct, indirect, and total operating costs have been demonstrated.

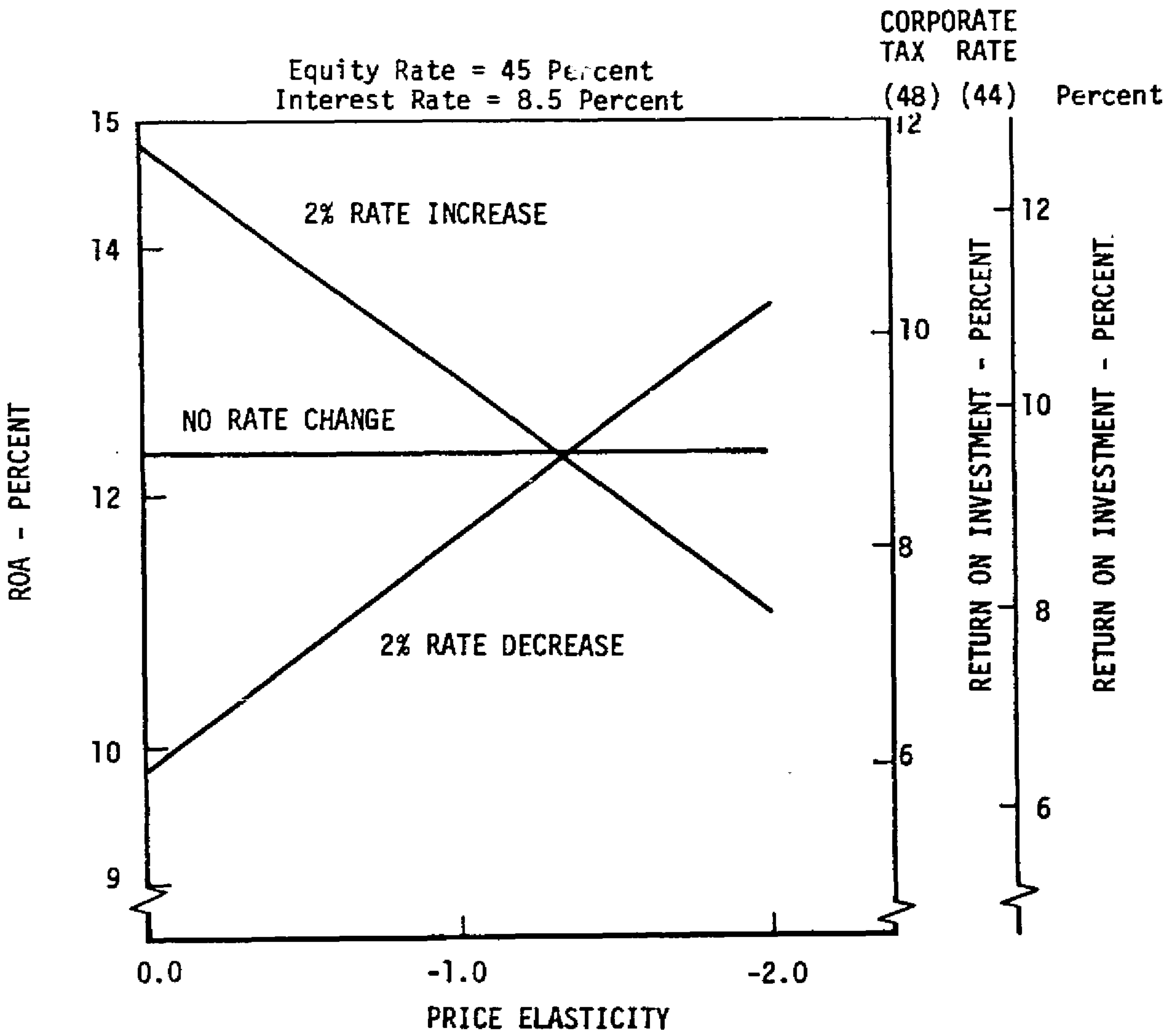

Figure 9-3. ROA and ROI vs Price Elasticity of Demand
1976 All-Cargo Operations
Short Run, 9.5 Percent/Annual External Growth

The retrospective analysis in Sections 7 through 9 have concluded:

- The direct operating cost economies have resulted from increased aircraft size combined with improved technology.
- The indirect operating costs economies have resulted from air cargo market growth stimulated by external econometric growth rather than tariff cuts.
- The profits of the air cargo industry have not been sufficient to induce, per se, further investment in the air cargo industry; rather, the investments have been made in anticipation of future profits rather than on the basis of current profits.
- The entry barriers that were preserved by government regulation provided stability within the industry.

The future of these salient observations may depend on the last one. In fact, the example of Federal Express suggests that radical changes may be in store for the air cargo industry as a whole and for individual firms in particular.

SECTION 10

IMPORTANCE OF RATE AND SERVICE ON FUTURE AIRCRAFT

The economic scenarios of Section 2 showed an externally induced growth rates of approximately 8 to 14 percent per annum for the domestic, U.S. international, and foreign markets. Previous analysis has shown the past demand to be relatively price inelastic and delivery time to be as important, or perhaps even more important, as price. In addition, there has been a long history of government regulation of the industry. These four trends have combined to produce an industry structure that has been highly resistant to tariff reductions. Advancing technology and increasing volume have led to significant economies of scale. In the regulated environment that has reigned in the past, members of the air cargo industry have been cost takers and price makers. Despite all positive influences, the air cargo industry has not yet been able to maintain consistent operating profits. For the most part, the time of profitability is still in the future.

The objective of this section is to draw inferences of the future air cargo market and the associated key events or changes that might encourage a strong and profitable air cargo industry. First, there is a consideration of the benefits of future aircraft technology. These benefits are then combined with the possibilities for indirect operating cost reduction to produce estimates of anticipated 1990 tariffs. These two analyses are used to project the structure of the 1990 air cargo market and the growth potential beyond 1990.

1990 Direct Operating Cost

Historically, aircraft technology has provided a base for making larger and, therefore, more efficient aircraft. At the same time, technology has been used to improve the economics of succeeding generations of aircraft vis a vis preceding ones of the same size. These two trends have supported the continuously improving economics of the air cargo industry in constant

terms. There is no reason to suppose that these two trends will reach a point of diminishing returns. New materials technology promises reduced weights and higher strengths leading to more efficient airplanes. It also implies the ability to manufacture larger airplanes than those presently in service. Active controls can reduce both drag and weight. Advanced engine technology with higher thrust-to-weight ratios and improved specific fuel consumption work across the size spectrum, improving the potential economics of advanced technology aircraft. The approach to calculating 1990 direct operating costs (DOC) compares a contemporary relatively efficient cargo aircraft with future conceptual designs. All the future aircraft extensively employ the advanced material, aerodynamics, and engine technologies.

Three conceptual advanced aircraft were selected from a stable of new aircraft outlined in Section 11. One is a multirole cargo aircraft with acceptable military characteristics that is as small a compromise as possible for the commercial air cargo market. The airplane chosen to represent this group has a design payload of 118 000 kilograms. This payload is virtually identical to the current airplane, the B747-200F. Two larger conceptual airplanes were selected. The first of these is a low-pressure 154 000 kilograms payload, dedicated, commercial cargo aircraft having low passenger capability and very little military application except for long haul of containers. The second all-cargo airplane, a relatively small spanloader, has a gross payload on the order of 317 000 kilograms. It should be pointed out that the spanloader efficiency improves with size. The data of Reference 10-1, for instance, indicates the optimum civil spanloader would have a gross payload of 635 000 kilograms. These conceptual designs are representative of three types of advanced aircraft with large applications of advanced technology. Comparative direct operating costs were calculated for these airplanes using modified ATA DOC methods.

The DOC for the four airplanes, the B747-200F, the dedicated commercial cargo, the spanloader, and the civil/military aircraft are shown in Figure 10-1. The DOCs for all four airplanes were calculated using a 70 percent load factor, the basic load factor used for the 1990 market. A comparison of the DOCs for the B747F and the civil/military aircraft shows

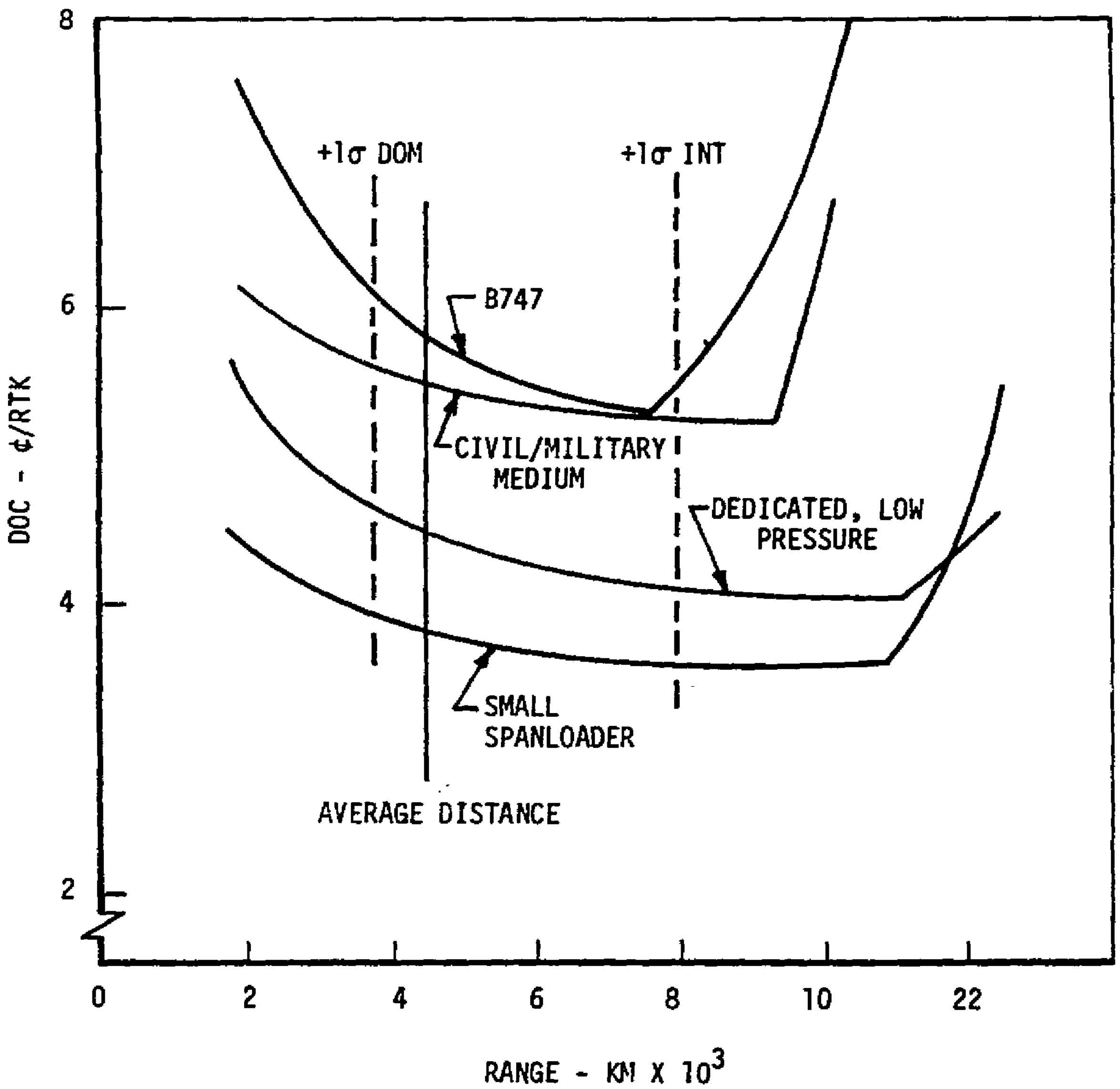

Figure 10-1. Comparative Direct Operating Costs
70 Percent Load Factor

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that advanced technology can be used to produce a compromised aircraft with improved economics given that the combined military and commercial market is large enough, as discussed in Section 8. Undoubtedly uncompromised commercial cargo aircraft would have much lower DOC than those of the compromised aircraft even at the same size scale. The effect of larger size is clearly shown in the DOC comparison between the dedicated low-pressure commercial and the span-loaded aircraft. The current sizing studies do not clearly separate the scale and technology effects; however, both these aircraft do exhibit superior economics to aircraft currently in service. The figure also displays the average weighted domestic and international flight distance revealed by 1976 revenue tonne-kilometer data. In addition, it shows the plus one sigma domestic and the plus one sigma international stage length. The large disparity between these two design points suggest that future markets, if large enough, could economically utilize two aircraft of different design ranges, payloads, and shapes.

These three advanced aircraft indicate what might be done with new technology. The subsequent translation of these direct operating costs into trip cost and shipment costs was done at the 4500-kilometer average distance used earlier to describe the representative shipment. It is not the most efficient point for any of these aircraft; therefore, the discussion does not compare optimized aircraft but rather typical costs associated with system operation.

Table 10-1 shows the calculated trip costs comparison of the four aircraft taken from the CLASS ATA equations. One of the important features of the table is the production run. The quantity pricing point for the B747-200F is not known. The low-pressure and spanload aircraft prices are based upon a production run of 200 aircraft and the civilian/military aircraft on a production run of 400 aircraft. This latter quantity was chosen to reflect the economic benefits that could accrue to offset the higher weight and relatively higher manufacturing cost of a compromised airplane. All three advanced aircraft feature lower cruise speeds than those of the B747-200F, having cruise Mach numbers of 0.72, 0.78, and 0.78, respectively, for the other three. As expected, the fuel costs decline for the advanced aircraft. This is particularly true for the spanloader where fuel costs on a

TABLE 10-1

DIRECT OPERATING TRIP COST COMPARISON -
CURRENT AND 1990 AIRCRAFT

Technology	Current	1990		
		Dedicated Cargo		
	B747-200F	Low Pressure	Span Loader	Civ/Mil
Production Run	?	200	200	400
Design Payload (kg)	117935	154223	317200	117935
(lb)	260000	340000	699300	260000
WPL @ 4500 km or 0.7 LF (kg)	82554	107956	222040	82554
Trip Time (Hours)	5.41	5.89	5.69	5.69
Fuel Cost	$ 8752	$ 8186	$ 16119	$ 8425
Other Costs	$ 8852	$ 7346	$ 8803	$ 6780
Depreciation	$ 3881	$ 6056	$ 13876	$ 5275
Total	$ 21485	$ 21588	$ 38789	$ 20480
¢/RTK	5.78	4.44	3.88	5.51
% B747-200F	100.0	76.8	67.1	95.3

tonne-kilometer basis would be significantly lower than either the B747-200F or the civilian military aircraft. Crew and maintenance costs also decline with the crew savings due to scale effect and the maintenance saving due to advanced maintenance technology. The scale effect is particularly noticeable in crew costs where crew size is not increased as the size of the aircraft increases.

The depreciation trend moves in the opposite direction from that for fuel and crew with the all-new aircraft exhibiting significantly higher depreciation costs. This increased depreciation cost is due to the relatively small markets projected for the large aircraft. The smaller potential market leads to higher program risk and, consequently, a cost-plus-profit manufacture pricing structure instead of the breakeven pricing strategy employed in costing aircraft with larger markets. The effect of advanced technology sales price is more complex. Advanced aircraft cost more than conventional aircraft with the same empty weight, but advanced aircraft cost less than conventional aircraft with the same payload. Higher depreciation costs,

therefore, reflect the net effect of two opposing trends-efficiency gains offset by the higher costs of the more efficient designs. Introduction of advanced technology aircraft into the air cargo fleets undoubtedly will require massive capital investments, thus increasing the capital intensity of the industry.

As would be anticipated, the direct operating costs per tonne-kilometer are significantly lower overall for the advanced aircraft than for the B747-200F, reaching a low of 67 percent for the spanloader. The marginally improved economics of a civil/military aircraft may not be attractive to the air cargo operator. If so, there are two approaches to improving its economics; (1) removing those military features which impose the largest penalties upon commercial air cargo operators or (2) an extension of the existing CRAF concept, side payments to the industry for operating the compromised aircraft. Side payments could take the form of either marginal pricing, i.e., selling the airplane "off the end of the line," or a discount below even the marginal price. While these ideas may seem radical, they are, in fact, rather minor extensions of the CRAF concept that provides the precedent.

The market/system evaluations discussed in Section 11 suggest that an aircraft of the size of the low-pressure airplane may have a viable market in the 1990 to 2000 time period, the vastly larger 1990 market could support an aircraft in the 154 000 kilogram design payload regime and achieve market sales on the order of 200 units. This air cargo market would be characterized by roughly proportionate traffic growth along current routes as augmented by a few new high-density routes and a greater number of new, less-dense routes. The new aircraft would service the high-density routes, and the older aircraft, economically displaced from the high-density segments, would serve the newer low-density routes. The production run of 200 units implies increased penetration of the total air cargo market by the largest aircraft from approximately 20 percent today to something approaching 40 percent in the year 2000. The market projection for the 317 000 kilogram payload spanloader is not as optimistic, suggesting that only approximately 100 of these aircraft would be required. A 100-aircraft production run would increase DOCs by approximately 17 percent according to Figure 8-6. This would raise

the trip cost to a level higher than that projected for the low-pressure cargo aircraft. Other Douglas studies have shown that advanced cargo aircraft with payloads in excess of roughly 175 000 kilograms face a very thin market where all too often the frequency of service criteria necessary for successful market capture are violated. While the low-pressure aircraft and the spanloader are carried through the analysis, less emphasis is placed on the spanloader because, despite market stimulation occurring subsequent to 1990, it still does not appear to be a reasonable air cargo aircraft until some time in the next century.

The direct operating cost (modified ATA) model, results as applied to the airplanes previously discussed, does not meet the real cost levels associated with current actual operations as given by CAB data. Accordingly, adjustments were made to relate the calculated trip costs to real trip costs associated with the previously considered typical 1000 kilogram, 4500 kilometer shipment. The B747-200F data provide a convenient basis for making this adjustment as shown in Table 10-2. The first B747 column shows the trip costs for the typical shipment as calculated from the first column of Table 10-1. The second column shows the actual 1976 trip costs. Both these costs computations were based upon a 70 percent load factor. (The 1976 average load factor was close to 65 percent.) It is not known whether or not the 1976 B747 experience reflects optimized operations. The third, fifth, and seventh columns show the 1000 kilogram, 4500 kilometer shipment costs as calculated for the respective aircraft using the modified ATA method. The fourth, sixth, and eighth columns show the forecast shipment costs computed by multiplying the calculated DOC by the ratio of the B747-200F costs displayed in columns one and two (modified ATA cost/actual cost). The adjustment factors are relatively small except for the depreciation and insurance cost element. If the current accounting system and depreciation assumptions are applied to the 1990 estimated costs, the capital costs would increase sharply. The effect would be to dilute the economies associated with the low-pressure air cargo airplane to 87 percent of current values as opposed to the calculated value of 77 percent. Depreciation is driven by four elements; aircraft price, utilization, useful life, and payload. The ATA costs of Tables 10-1 and 10-2 were based upon a depreciation period of 15 years.

TABLE 10-2

CALCULATED AND ADJUSTED CARGO AIRCRAFT SHIPMENT DIRECT OPERATING COSTS, 70 PERCENT LOAD FACTOR 1000-KILOGRAM SHIPMENT 4500 KILOMETER

Cost Classification	AIRCRAFT							
	B747-200F		Low Pressure		Span Loader		Civil-Military	
	Trip Cost Mod. ATA	Actual	Trip Cost Mod. ATA	Forecast	Trip Cost Mod. ATA	Forecast	Trip Cost Mod. ATA	Forecast
Fuel	$106	$130	$ 76	$ 93	$ 72	$ 88	$102	$125
OPS	107	111	68	71	39	41	82	85
Depreciation and Insurance	47	139	56	166	62	184	64	189
Total	$260	$380	$200	$330	$173	$313	$258	$399
Calculated DOC Index	100		77		66		99	
Adjusted DOC Index		100		87		82		105

Reducing depreciation costs, therefore, requires reducing the initial price, increasing utilization, or increasing the estimated useful life.

One of the primary determinants of initial price, as pointed out earlier in this section, is the production run. Long production runs of commercial jet aircraft have been the exception rather than the rule. This underscores the economic importance of multirole design to increase the market. If this is not possible, or desirable, it may lead to consortium design and manufacture of all-cargo aircraft. If a consortium approach, which would limit the all-cargo designs offered for sale, is in the public interest, then legislative antitrust exemption or tacit administrative concurrence must be realized.

The other avenue to reducing the depreciation component is longer useful life. Stretching the depreciation period to, say 20 years, may be historically justified. However, conservative accounting practices coupled with a rapidly changing air cargo industry would militate against wide acceptance of longer aircraft depreciation periods. Therefore, the potential for reducing depreciation costs, which merely reflect capital costs and risks, is greater in the design and manufacturing area than in the air cargo industry accounting practices.

One of the biggest benefits accruing to the 1990 system by virtue of increasing concentration along the major routes is the load factor increase from 65 to 70 percent. This change alone will reduce the direct operating costs by 7 percent below 1976 levels without occasioning additional investment.

1990 Total Shipment Costs

The IOC and terminal cost elements developed in Section 8 together with the DOC just presented (Table 10-2) were confined to provide an estimated total shipment costs in the 1990 time period based upon the typical shipment of 1000 kilograms at a stage length of 4500 kilometers. The familiar 1976

(Table 9-2) shipment results are displayed in the first column of Table 10-3. The remainder depict the costs and tariffs for possible future combinations of ground and air system evolution as described in the next several pages. Three conceptual aircraft, namely a small derivative 41 000-kilogram payload near-term aircraft, the larger low-pressure design with a 154 000-kilogram payload, and the small 317 000 kilogram span loader, are displayed for each of three ground systems. The cost for the near-term, derivative aircraft were calculated using the modified ATA DOC method. Because this aircraft does not employ 1990 technology, the cost calculations were omitted from previous discussions. The three ground systems are an evolutionary ground system (E-1) illustrating the cost impact of going from onsite packing of containers to offsite packing of containers, the E-2 ground system, and E-3 ground system described in Section 3. The last two systems employ increased terminal mechanization and automation in addition to off-site container packing. The airplane load factors are 65 percent for the 1976 reference costs and 70 percent for the 1990 costs.

Line-haul costs, DOC, decline to the forecast actual levels shown in Table 10-2 for the low-pressure and spanloader aircraft with comparable values computed for the near-term aircraft. The other major components of total air cargo operating cost reductions are terminal and corporate operations. Aircraft service costs, i.e., those costs associated with fueling and servicing the airplane on the ground have been reduced by a factor of 20 percent for the advanced aircraft as a result of the increased attention being paid to aircraft/airport compatibility. Traffic service costs have been reduced drastically in accordance with the findings of the terminal study of Section 3. The incremental benefits of higher automation, while significant, are relatively small once the 90-percent shipper-packer container system evolves. Sales and promotion expenses should decline on a shipment basis simply as a result of increased volume, according to the indirect operating cost slope displayed in Figure 8-2. However, commissions are a direct cost of acquiring additional volume, and increased emphasis must be placed upon acquiring new customers for the 1990 system if the total air cargo market is to expand. Therefore, commissions paid to either outside agencies or air cargo expediters are held constant. General and administrative expense will follow the IOC trend curve displayed in Figure 8-2. Ground facilities cost

TABLE 10-3

COSTS, TARIFF, AND PROFITS — 1000-KILOGRAM SHIPMENT 4500 KILOMETERS

		Evolutionary Ground System			E2 Ground System			E3 Ground System		
			Advanced Aircraft			Advanced Aircraft			Advanced Aircraft	
	1976 Results	Near-Term Aircraft	Low Pressure	Small Span Loader	Near-Term Aircraft	Low Pressure	Small Span Loader	Near-Term Aircraft	Low Pressure	Small Span Loader
Load Factor (%)	65	70	70	70	70	70	70	70	70	70
Line Haul ($)										
Fuel	$140	$215	$ 93	$ 88	$215	$ 93	$ 88	$215	$ 93	$ 88
Operating	120	203	71	41	203	71	41	203	71	41
Aircraft Dep + Ins	150	227	166	184	227	166	184	227	166	184
Total DOC	410	645	330	313	645	330	313	645	330	313
Terminal + Corps ($)										
Aircraft Service	45	45	36	36	45	36	36	45	36	36
Traffic Service	115	42	42	42	32	32	32	28	28	28
Sales and Promotion	40	19	19	19	19	19	19	19	19	19
Commissions	25	25	25	25	25	25	25	25	25	25
G&A	40	19	19	19	19	19	19	19	19	19
Ground Facilities	15	11	11	11	8	8	8	8	8	8
Total IOC	$280	$161	$152	$152	$148	$139	$139	$144	$135	$135
Total Cost ($)	690	806	482	465	793	469	452	789	465	448
Operator Profit ($)	25	73	53	59	73	53	59	73	53	59
Total Tariff ($)	$715	$879	$535	$524	$866	$522	$511	$852	$518	$507
% Current Tariff	100	123	75	73	121	73	71	121	72	71

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will decline despite increased investment required for the E-2 and E-3 ground systems as a result of spreading the relatively fixed costs over larger volumes.

Although the near-term aircraft systems do not compare well with the B747F in Table 10-3, this comparison on the basis of the 4500-kilometer stage length can be misleading. These aircraft are, in fact, more economical at their design range than current aircraft as shown by the market/system analysis of Section 11. Their relatively small share of RTKs means that they will not be the dominant influence leading to establishing lower tariffs for the air cargo system as a whole.

The low-pressure aircraft that could enter the air cargo fleets in sizeable numbers by mid-1990s would allow tariff reductions of 25 to 28 percent on its operations depending upon the ground systems employed as shown in the bottom line of Table 10-3. At these tariffs, sufficient dense route profits would be generated to induce investment in these uncompromised all-cargo aircraft. The small spanloader, which does not appear strongly in the 1990s market/system analyses (Section 11) would offer significantly lower costs than the low-pressure aircraft. However, either new route network concepts must be implemented and/or key routes must grow by much larger factors than are projected for the air cargo system as a whole for even small spanloaders to be economically viable in the 1990 to 2000 time frame.

Advanced technology terminals offer relatively small cost savings over the 90-percent shipper-packed container system E-1, as discussed in Section 3. The total increment that can be gained amounts to at most 3 percent of current nominal tariffs. This slight advantage suggests that intensive terminal automation programs will be undertaken voluntarily only if terminal capacities are inadequate or if the performance risk of the advanced systems is small.

Total cost on high-density routes could decline by as much as 33 percent with the low-pressure aircraft (Table 10-3) depending on the final state of the air cargo system. The 33 percent cost reduction is a result of a 20 percent decline in direct operating costs, of which 7 percent can be attributed to a load factor increase of 65 to 70 percent, plus a 51 percent decline

in indirect operating costs, primarily a function of the 90 percent shipper-packer container system (Section 3) and returns to scale from increased volume through the system (Section 8).

Table 10-3 also displays a significant shift in the indirect operating costs (IOC)to direct operating costs (DOC) ratio over the 1976 to 1990 time period. Table 10-3 shows 1976 IOCs amount to 40 percent of total cost or about 68 percent of DOCs, while the forecasted 1990 IOCs amount to 29 percent of total cost or 40 percent of DOCs. In 1976, 39 cents of each revenue dollar went to IOCs. By 1990, IOCs on high-density routes should require only 26 cents of each revenue dollar.

The projected 1990 results show sharply increased profits. The profit forecast shown in Table 10-3 has an investment base of flight equipment plus spares plus another 33 percent of the sum for working capital. The tabular results provide a 12 percent posttax return for 100 percent equity financing. A 50 percent long-term debt capital structure would reduce the operating profit required from $53 to $38 at current corporate tax rates, which translates to a tariff reduction of 3 percent. Although increased profits dilute the tariff reductions, the increased scale of operations and advanced technology can provide significant real tariff reductions on high-density routes.

1990 Rate Setting

To examine rate-setting behavior for the 1990 system, it is necessary to estimate short- and long-run costs analogous to the estimates presented earlier for short-run rate setting. The estimated costs shown in Table 10-4, for combination and all-cargo carriers for the 1990 time period are based upon Table 10-3. The very long run all-cargo costs shown are identical to the next to last column in Table 10-3. The short-run costs estimates for both classes of carriers follow the logic described in the discussion of Table 9-1. The center column for each class illustrates long-run costs, including capital, for a 100 percent equity capital structure and an 8.5 percent average return on investment. The left-hand column is the familiar 1976 baseline cost distribution. These data once again exhibit a wide range of rational tariffs

TABLE 10-4

SHORT-RUN AND LONG-RUN COSTS — 1990 SYSTEM

1000-Kilogram SHIPMENT 4500 Kilometer

	1976 Results	Low-Pressure Dedicated Aircraft					
		Combination Carrier			All-Cargo Carrier		
		Term			Term		
		Short	Long	Very Long	Short	Long	Very Long
Fuel ations	$ 140	$ 17	$ 60	$ 60	$ 30	$ 93	$ 93
Operations	120	10	44	40	9	71	71
Depreciation	150	-	110	110	-	166	166
TOTAL DOC	$410	$ 27	$115	$214	$ 39	$330	$330
Aircraft Service	45	-	-	-	-	36	36
Traffic Service	115	12	28	28	12	28	28
Sales Promotion	40	-	10	10	-	19	19
Commissions	25	25	25	25	25	25	25
General and Administration	40	-	10	10	-	19	19
Ground Facilities	15	-	-	4	-	8	8
Total IOC	$280	$ 37	$ 73	$ 77	$ 37	$135	$135
Total Cost	$690	$ 64	$198	$291	$ 74	$465	$465
Operating Profit	25		3	38		38	53
Total Tariff	$715	$ 64	$201	$230	$ 74	$503	$518
Percent Current Tariff	100	9	28	32	10	70	72

ranging from a short run low of $64, for the typical 1000 kilogram, 4500 kilometer shipment by a combination carrier to a very long run high of $518. All-cargo tariffs must be higher than combination tariffs because the all-cargo carrier must recover all costs including capital from cargo, while the combination carriers can rationalize some degree of by-product costing. Comparison of the all-cargo short-run cost to long-run average cost, $74 and $465, shows 1990 short-run costs are about 16 percent of long-run costs as opposed to 18 percent for the earlier 1976 analysis (Table 9-2). This occurs because the depreciation cost component has grown while almost all other costs have declined.

Section 9 focused attention on short-term as opposed to long-run rate making. Here the profit picture as projected, is improved and the cost structure has changed. These features require changes to the ROA equation presented in Section 9. The first change is correcting the ROA normalizing factor from 1.1 to 2.07. This factor relates the nondimensional results into an appropriate ROA level in before-tax terms. The next change is a correction to the revenue to average cost ratio, 1.036 in 1976, to 1.114 (465/-518) from Table 10-3. The final change corrects the marginal to average cost ratio of 0.18 for the 1976 short-run analysis to 0.74. This is equivalent to a long-run incremental cost per shipment of $344, total average cost of $465 less sales promotion, general and administrative expense, and ground facilities and less $75 accounting for working capital, spare parts pools, and other relatively fixed direct operating costs. The resulting equation is:

$$\mathrm{ROA} = 2.07 \left\{ 1.114 \frac{Y}{Y_0} \left\{ 1 + \Delta G + \varepsilon \frac{\Delta Y}{Y_0} \right\} - 1 + 0.74 \left(\Delta G + \varepsilon \frac{\Delta Y}{Y_0} \right) \right\}$$

The long-term scenario-related plots were calculated. One for an external growth rate, ΔG, of 10 percent and one for an external growth rate of zero. The latter depicts a growth rate typical of a mature industry. Figure 10-2, analogous to Figure 9-3, shows the cross-over regions appropriate to scenario 2, the horizontal line; scenario 1, the upward sloping line; and scenario 3, the downward sloping line (Section 2). All three lines converge at an elasticity of about -3.4 for the 10 percent growth case and about -3.1 for the zero growth case. This means long-run rate-making behavior would be even more conservative than short-run behavior because volume-inducing rate

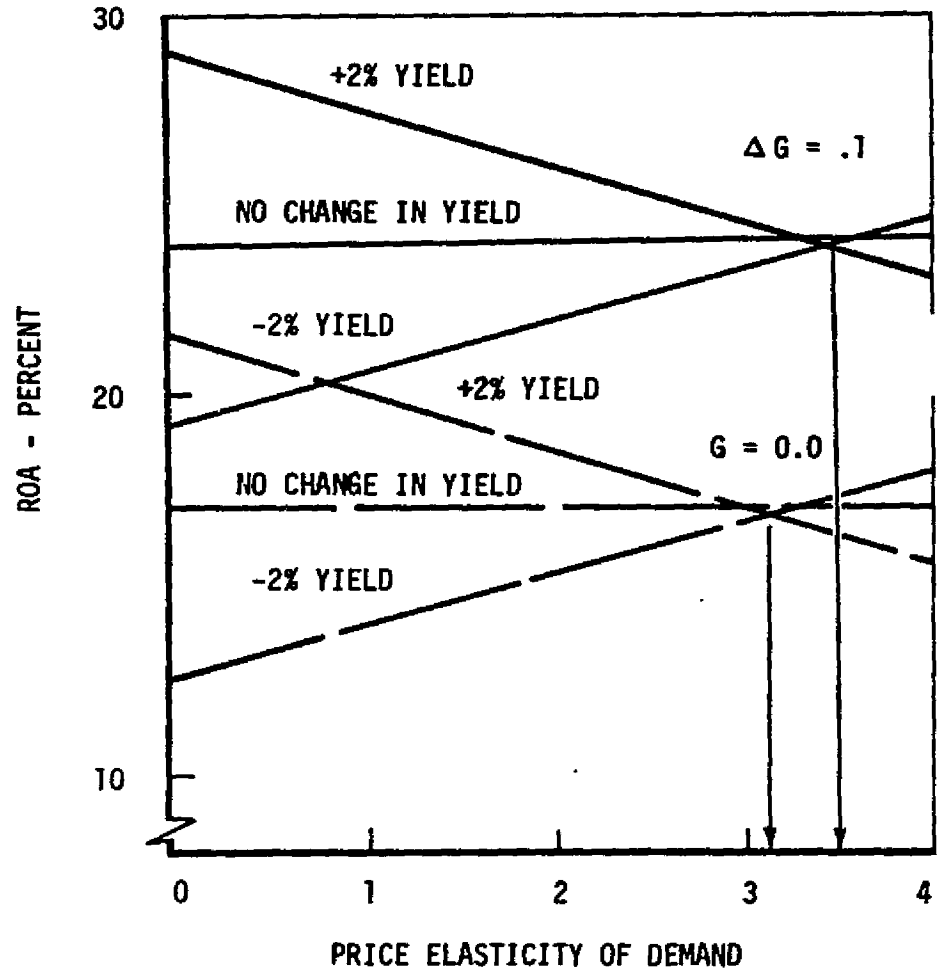

Figure 10-2. Long-Term ROA and Price Elasticity

reductions will be made only in highly elastic markets. Therefore, there will be a strong general tendency toward stability. In time, some volume-inducing reductions will be made, but the industry left to itself probably will not engage in wide-spread price cutting.

It is now possible to generalize the short- and long-run rate-setting results. The relationship between the elasticity of demand and marginal cost to average cost ratio, 0.18 short term and 0.75 long term, is central. There exists a locus of indifference points with an elasticity coordinate and a cost ratio coordinate; this locus separates the two pricing strategies. One such locus is shown in Figure 10-3. When the price elasticity of demand is unity and the marginal cost to average cost ratio is zero, price increases are exactly offset by demand decreases (of course, this situation does not exist in the real world). At the other end of the spectrum, the locus ordinate approaches infinity. If the marginal cost to average cost ratio is unity, the indifference elasticity would be infinite. All the available evidence from the air cargo industry suggests that the relationship between elasticity and marginal costs to average cost ratio is such that maintaining or increasing prices is a rational and profit-maximizing strategy. In the real world, this probably means that tariffs tend to remain stable for long periods due to the established industry members probably hesitating to raise prices out of concern for the thought that competitors would not follow. After all, eventually the time would come when increased volume would make up for the risks associated with raising prices. When, however, the cost structure undergoes a quantum jump, for example, after the 1973 oil embargo and price increase, there would be little hesitancy for established industry members to raise tariffs.

The tendency toward stable or increasing tariffs was prevelant during the period of government regulation. It remains to be seen whether or not the posture will be as pervasive during the years to come. Part of the answer lies in the entry of new firms into the air cargo industry. As pointed out earlier, Federal Express is a classic example, being a real-world archetype of Leftwich's entrant under oligopolistic conditions. Entry into the air cargo industry still is limited by capital requirements even though the legal bars to entry have been greatly diminished if not eliminated. Nevertheless,

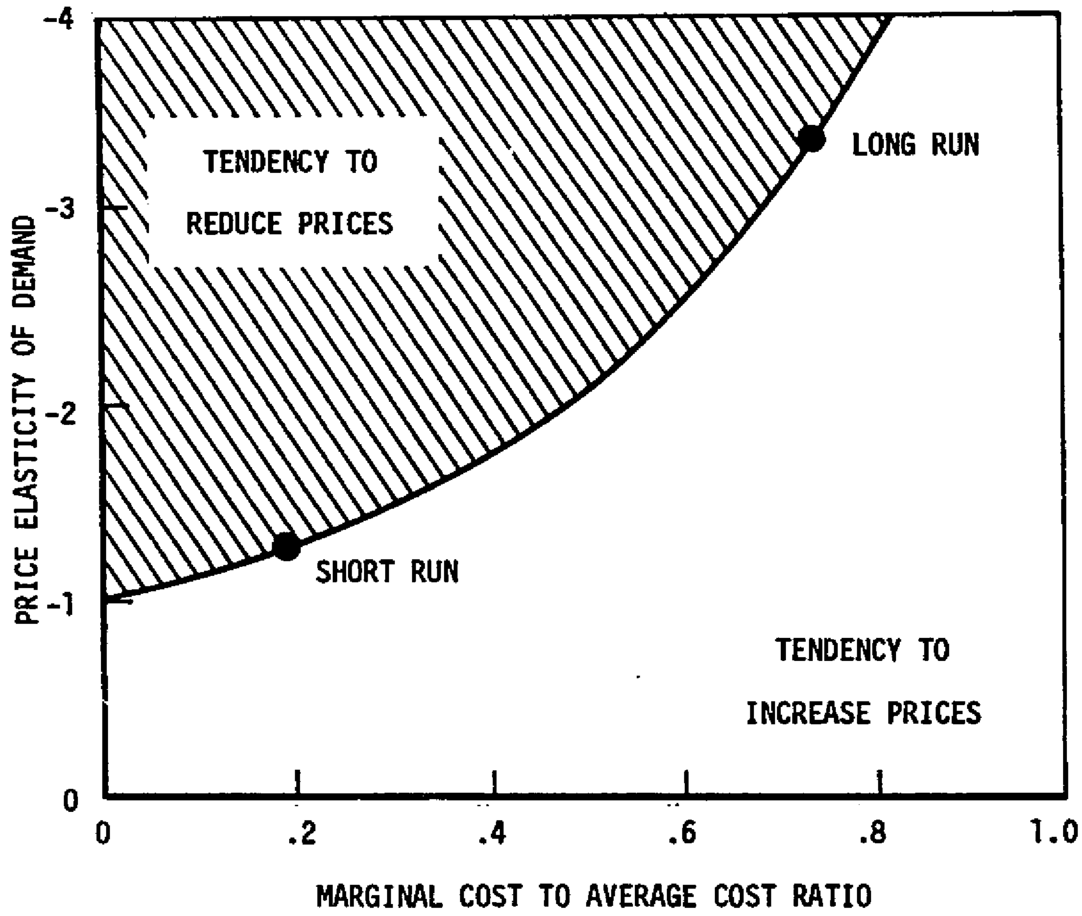

Figure 10-3. Elasticity, Costs, and Rate-Setting Behavior

as the market grows and profits generated by stable prices begin to accrue, new firms will be attracted to profits generated in the air cargo industry. There are, therefore, incentives for and barriers against new entrants.

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Future Industry Structure

The analysis up to this point has viewed the market as a homogeneous aggregate. Clearly this is not the case, there are many markets for air cargo, some with higher elasticities than others. Furthermore, in some markets, air transportation is more competitive with ground transportation than in other markets. Obviously, there are markets where specialized operators can reduce their costs to the point where the larger general air cargo carrier may not be able to compete profitably. Examples of these markets are the Federal Express approach and the innovative plan put forward by International Husky. The idea behind the latter proposal was to design a large specialized aircraft for carrying automobiles. It was to be an integral part of the auto industry's distribution sytem (the Federal Express capital investment was a fraction of the capital required by International Husky.) Under deregulation, new entry by specialized operators is anticipated. Further, these operators will tend to destabilize the operations of the established air cargo carriers. It is, therefore, reasonable to foresee a deregulated air cargo industry that will be much more competitive than a regulated one. With new entrants will come increased emphasis upon price competition as the new firms attempt to win away markets from the established firms. The competition between new and older firms probably will spread until there is competition among the older firms themselves. Over the long run, it is anticipated that there will be fewer large firms, but those that survive will be larger. This surviving core will share the total air cargo market with a number of smaller and newer firms, each one specializing in a segment of the market.

Not all competitive strategies will be price competition, e.g., earlier delivery time is an effective nonprice marketing tool. At least in the earlier stages of the deregulated air cargo industry's transformation service competition should grow. There are two primary ways for service to grow,

improved point-to-point delivery time and extension of present air cargo route structures so that one operator can serve more cities and, therefore, more customers. It is this latter mode of nonprice competition that will soon create price competition. Expanding firms will attempt to serve more points. Ultimately, this will lead to market confrontations between the newer entrants into an existing market and more established operators. Successful establishment of new routes will feature both nonprice and price competition. Better service will be matched by better service. Inevitably, local and temporary price concessions will be made leading to retaliatory pricing to maintain market shares. During this process, the weaker operators will be forced to abandon markets leading to the increased dominance of the industry by a few members. Over the long run, there will be a tendency to at least temporarily reduce tariffs in currently stable submarkets.

There is, of course, always the possibility of a return, to a lesser or greater extent, to a regulated industry structure. Whether or not this occurs will depend, in a large measure, upon the evolving competitive practices within the air cargo industry. For example, rampant price competition that operates to the public's benefit in the short run may not be desirable in the long run, e.g., monopolistic dominance of a firm in an unregulated market. If the long run, implications of such behavior are serious enough; there will be demands by all segments of the industry to reimpose some regulation.

There is another questionable assumption underlying the present analysis, the assumption that increasing GNP almost necessarily implies increasing use of air cargo as a tool. This may not be the case. The energy intensiveness of air transportation coupled with diminishing world energy reserves could weaken the historic relationship between national product growth and growth in the air cargo industry. Further weakness could be introduced by major changes in the import/export postures of lesser developed countries and even in the interregional import/export relations within a given country. In 1978, this does not seem to be a major concern. However, a forecast into the next century might find these import/export posture changes becoming stronger. This would, of course, radically change not only the magnitude of air cargo transportation but the physical characteristics of the cargo as well. While there is a strong presumption to believe that growth of the air cargo industry

and the nature of the shipments flowing through it are immutable, the presumption may not be true for the post-1990 period. Extension of air cargo penetration into the total transportation market would certainly change the characteristics of the post-1990 air cargo by introducing "heavier" commodities. As we approach the turn of the century, this, in turn, would change the requirements for air cargo airplanes designed for future markets.

Current thinking and planning, based upon the most probable scenario strongly suggest the need for new and larger aircraft during the final decade of this century. What kind of impact might it have? Suppose, for example, the low-pressure all-cargo airplane were introduced into commercial service in the 1990 time period. Large cargo aircraft in use today haul about 20-percent of the total air cargo moved as shown by the market/system analysis of Section 11. If the high-density routes continue to grow, large aircraft could be expected to capture larger portions of these expanded routes.

The data presented in Figure 10-4 consider the potential of the previously discussed low-pressure commercial cargo aircraft to penetrate the growing market defined by the combined domestic and U.S. International baseline growth scenario of Section 2. For simplicity, a straight line logarithmic projection, 12-percent per annum, has been used to forecast the GNP-induced market growth over the years 1990 to 2000. The revenue tonne-kilometers captured by the new aircraft are indicated by the volume under the shaded area in the lower central portion of the figure. The shaded area represents the band of capture uncertainty with the midband representing 45 percent of the market in the year 2000. This capture occurs rapidly during the period from mid-1991 introduction to the year 2000. The cost data presented earlier for the E-1 ground systems (Table 10-3) depicted the tariff reductions that might be possible with the low pressure cargo aircraft based upon potential aircraft production roughly commensurate with the results of the market/system analysis of Section 11.

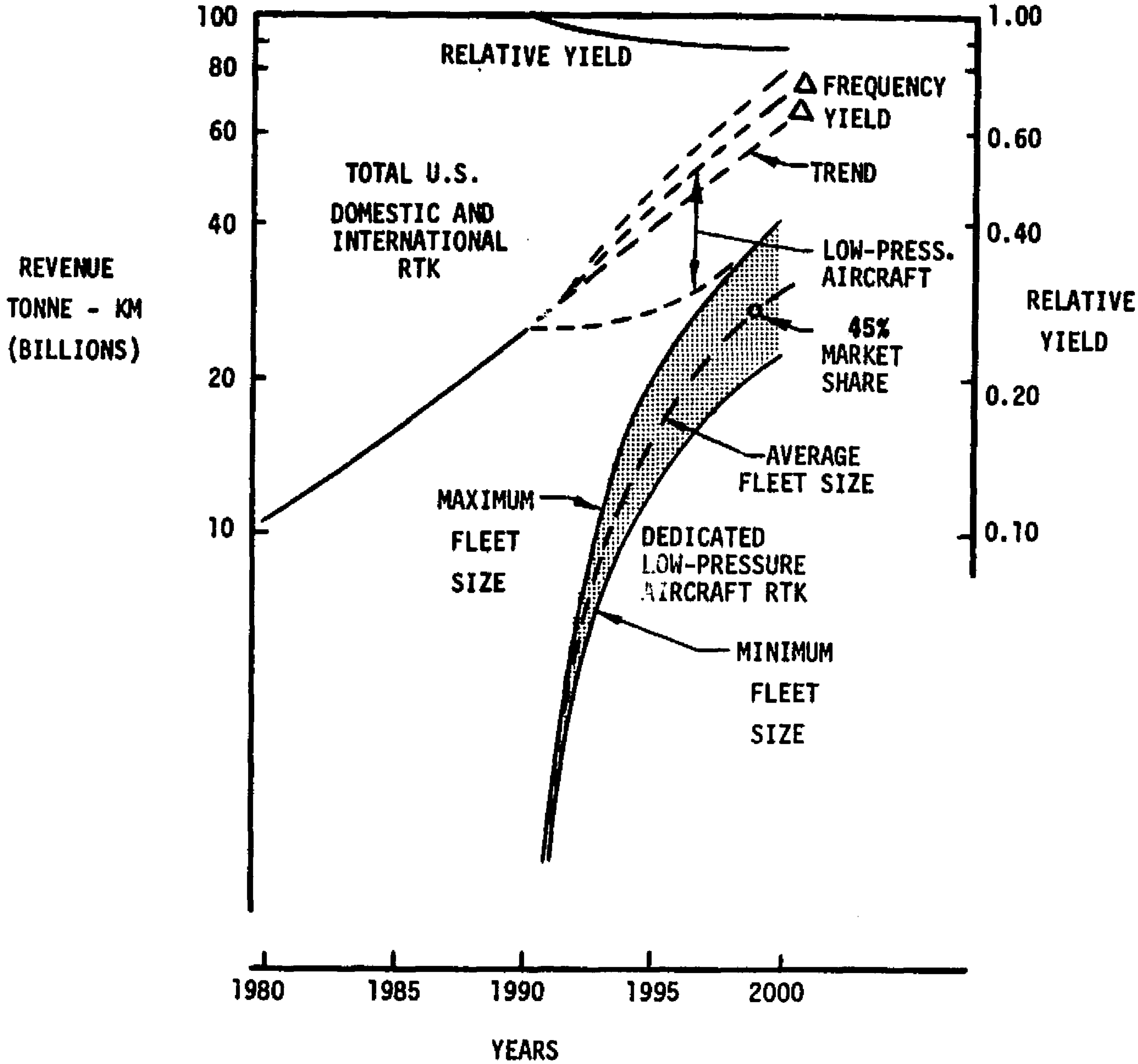

Figure 10-4. Total U.S. Market, Relative Yield, Market Penetration and Added Growth, 1980 to 2000

Annual relative yield obtained as the new aircraft penetrate the market is shown in the upper portion of the Figure 10-4. These yield values were calculated by relating the number of tonne-kilometers produced by the new aircraft to the tonne-kilometers captured by older, less-efficient aircraft at higher yields. Analysis considered only the tariff reduction due to decreased DOC since it was assumed that the tariff reductions due to decreased IOC (i.e., shipper-loaded containers) will be implemented by 1990. The relative yield sharply declines at first and then begins to flatten as the low-pressure large aircraft market becomes mature. The increased demand induced by these yield reductions was calculated using the all-jet cargo model presented in Section 7. At the end of the 10 year period, 1990-2000, the introduction of the large aircraft will add 13 percent to the baseline projection as indicated by the Δ yield interval. The market penetration is shown twice. The lower shaded area indicates the likely upper and lower bounds of RTKM captured by the aircraft with the average of the band superimposed onto total RTK lines. The lower limit shows the RTK that would be captured by then current aircraft until 1990 and by still more advanced aircraft beginning in 1994. By the year 2000, there would be a cumulative market requirement for still newer cargo aircraft amounting to over 50 percent of the 1990 market.

The role of increased service has been shown to be significant by the results presented in Section 7. Service can be improved in at least two ways, reduced delivery time and an increased number of destinations served. Both of these can stimulate market growth. The increased demand due to a 20-percent increase in service was calculated using the all-jet model presented in Section 7. Over the 10 year period, this could amount to a growth of 10 percent or almost 1 percent per annum on a compound basis, as shown by the Δ frequency interval of Figure 10-4.

This section of the study addressed three major issues:

- Can DOCs be reduced by 30 percent?
- Can IOCs be reduced by 40 percent?
- Can TOCs be reduced by 45 percent?

A fourth issue arising out of the third, has been added. If, indeed, the total operating cost can be reduced by 45 percent. may tariffs also be reduced by 45 percent? The results are listed below:

- Direct operating cost may be reduced by 7 percent merely by increasing the load factor from the 65 percent that was obtained during 1976 to 70 percent, which should be attainable in 1990 through better load planning and container loading.

- Increased aircraft size and improved aircraft technology can reduce direct operating cost by another 13 to 23 percent (the latter is the ATA computed value of Table 10-2) as described earlier in this section. However, this would affect the DOCs of only the new aircraft.

- This shift to 90-percent shipper-packed containers would reduce IOCs by 23 percent. (Sections 3 and 8). This is the largest single IOC reduction that is available.

- External market growth combined with returns to scale particularly in the sales promotion and general and administrative expense IOC would reduce total IOC by 15 percent (Section 8).

- Continued emphasis on airport/airplane compatibility could reduce IOC by 4 percent. This improvement primarily would be achieved by improving the aircraft/airport interface during turnaround operations including fueling (Section 10)

- Improved terminal technology could reduce IOC by an additional 6 percent above the improvement provided by 90 percent shipper-packed containers (Sections 3 and 8).

The results indicate direct operating costs can be reduced by 20 to 30 percent and indirect operating costs can be reduced by about 48 percent as shown in the first two columns of Table 10-5. These reductions in direct and indirect operating costs are translated into reductions in total operating costs in column three. When combined in the 1990 to 2000 operating environment, they

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TABLE 10-5

THE BOTTOM LINE

Major Issues	New Dedicated Aircraft: Reduce DOC by 30%	New Dedicated Aircraft: Reduce IOC by 40%	New Dedicated Aircraft: Reduce TOC by 45%	Fleet: Reduce Tariffs by 45%
Increased Load Factor	7%		4%	4%
Increased Aircraft Size and Improved Technology	13-23%		7-12%	3-6%
90% Shipper-Packed Container		23%	10%	9%
Increased Market		15%	6%	6%
Improved Terminal Technology		6%	2%	2%
Emphasis on Aircraft/Airport Compatibility		4%	1%	1%
Increased Airline Profit				-4%
Total	20-30%	48%	30-35%	21-24%

amount to a total operating cost reduction of 30 to 35 percent for the new aircraft. This is not the answer, however, to the fourth, added, issue. The improvement is more modest. Since the operating cost reduction arising from increased aircraft size and improved technology would affect only one-half of the fleet, the total savings must be appropriately adjusted to the tariff values shown in column four. The shift from cost to tariffs requires a slight downward adjustment to the packed containers savings from 10 to 9 percent due to the profit element. In addition, capital must be forthcoming to finance these improvements as shown by increased profits. Therefore, post-1990 tariffs could be reduced by only approximately 21 to 24 percent on an across-the-board basis.

1990 Joint Military/Commercial Potential

The CLASS studies emphasis on the air cargo system does not provide a definitive evaluation of the potential savings to the air cargo systems of joint military/commercial operations and joint military/commercial development of new cargo aircraft. This question can only be answered through more

detailed design studies involving the three air cargo aircraft development strategies presented earlier, joint cargo/military, joint passenger/cargo, and dedicated commercial cargo.

The results of the current study have not quantitatively identified the potential impact of "joint tenancy" upon air cargo freight rates. While there may be some economic savings, these would be offset either fully or in part by increases in the door-to-door delivery time that is the paramount commodity produced by the air cargo industry. The steep slope of the utility versus delivery time relation in Figure 7-3 suggests minor delays may degrade the quality of air cargo service. This would occur when an hour delay resulted in delivery at 9:00 a.m. as opposed to 8:00 a.m. Customer attitudes in past cargo surveys have expressed high preference for discrete delivery periods "before the doors are open" or "before noon." Administrative options that can impinge on the designed delivery periods may have a greater impact than it would seem. Conversely, in other circumstances and particularly along international routes rather long delivery time delays may be tolerated before the "delayed delivery" threshold of air cargo customers is breached.

The results of the comparison of conceptual cargo aircraft design suggest that all-cargo aircraft could come into the market during the 1990-2000 time frame. The viability of this approach must be evaluated against the benefits of both joint commercial/passenger and joint commercial/military cargo aircraft before final evaluation.

Trends and Developments Affecting the Air Cargo Industry

Deregulation was identified as one of the most significant developments affecting the air cargo industry over the next two decades. The Federal Express scenario points out the necessity for maintaining a competitive air cargo industry to bring maximum benefits to the United States economy. Maintaining the competitive character may require strong, conventional regulatory action. Antitrust enforcement is a prime example; maintaining access to the capital markets is another. Without these actions, the industry may tend to be more concentrated with the attendant risk of becoming less

innovative. Although there may be significant synergistic effects from an integrated air cargo industry, the record suggests many major innovations are the contributions of new entrants.

Beyond deregulation, there are a number of other structural changes and technological advances that may be beneficial. Many of these influences may operate less directly than those previously discussed. When this occurs, it is difficult to quantify the benefits. It is possible, however, to order these to identify the most important ones within a class. Twenty-four trends were grouped into three broad classes, technological, operational, and institutional. Each influence was evaluated to determine the potential primary benefit or injury to 20 separate items comprising six broad elements of air cargo aircraft and/or the air cargo industry: the cargo aircraft itself, direct operating costs, indirect operating costs, revenue, service, and the infrastructure. The 24 trends and the 20 items are displayed in Table 10-6. Each intersection in the matrix was considered separately. If the trend has a beneficial influence, a plus was entered; if negative, a minus was entered. Since volume effects could not be identified in isolation, a plus was entered if the sum of the service entries was positive. The infrastructure entries were ignored, in affect, assuming the infrastructure would have to follow the mainstream development.

The matrix provides a scheme of establishing a benefit index for each trend, i.e., the sum of the entries. From this, a benefit rank was established for each class of trends, technological, operational, and institutional. The high ranking influences are:

- Aerodynamic advances ranks highest among technologies followed by container structure and area navigation.

- Block time, dedicated airports, and terminal automation ranked first among the operational trends; but their indices are not as large as the indices for technologies.

- A dedicated air cargo fleed was the first-rank institutional influence.

TABLE 10-6

SCREENING MATRIX OF TECHNOLOGY, OPERATIONS, OPTIONS AND INSTITUTIONAL ARRANGEMENTS AND THEIR IMPACT UPON ENHANCING THE ECONOMIC VIABILITY OF THE AIR CARGO INDUSTRY

Trends \ Elements Impacted		Aircraft / DOC								IOC			Rev.	Service				Infra-structure					
		WPL/TOGW	Cruise Speed	Range	No. of Aircraft	Acquisition Cost	Fuel	Crew	Maintenance	Aircraft Service	Terminals	General and Administrative	Volume	Security	Single Way Bill	Shipping Time	Shipping Cost	Airport	Airway	Forwarder	Interface	Benefit Index	Benefit Rank
Technologies	Aircraft Structure	+				-			+				+				+				+	2	4
	Container Structure	+				+			+				+				+					4	2
	Engine Technology	+					+		-				+			+	+	+				2	4
	Fuel Technology	+					+		-				+				+					2	4
	Aerodynamics	+	+	+		-	+		+		+		+				+					5	1
	Interior Design					-			+		+		+				+					2	4
	Active Controls		+	+		-	+		-				+			+	+		+			2	4
	In-Transit Control										+											1	5
	Area Navigation		+				+	+														3	3
Air Ground Operations	Door-to-Door	-									+		+		+	+	+					1	2
	Hub/Spoke	-					-	-			+		+			+	+			+		1	2
	Multi-Stop					-	-	-														3	3
	Block Time		-				+	-					+				+					2	1
	Remote Terminals						±				+			-		-	+	+		+		1	2
	Dedicated Airports						±				+		+	+				+	-	+	+	2	1
	Terminal Automation										+		+	+	+	+	+					2	1
	Joint Loading										+			-							-	1	2
Institutional	Joint Rates	+			+								+		+			-	-	+	+	3	3
	Intermodal Containers					-					+		+	+			+			-	-	1	5
	Presealed Containers										+		+	+	+	+	+			+	+	2	4
	Dedicated Fleet	+			-	+	+		+		+		+	+				-	-			5	1
	Specialized Carriers					+	+				+		+	+								4	2
	Block Capacity Rates				-								+				+						
	Joint Use										+		+				+			+		2	4
	Focus Index	9	4	2	5	9	12	4	7		14		19	8	4	7	16	5	4	7	6		
	Impact Index	5	2	2	1	3	6		1		14		19	4	4	5	16	1	2	5	2		

A similar procedure was used to identify the items impacted most frequently as embodied in the focus index, the number of entries in a column. The impact index measured which items might experience the most positive impact. It is the net positive sum of the entries. The items with the highest focus index were volume and shipping cost reductions followed by terminal and fuel improvement, payload fraction, and acquisition cost. In the net impact terms the rankings were volume, shipping cost, terminals, and fuel.

Improvement in aerodynamics appears as a first priority item on every list of recommendations for increasing aircraft efficiency. The rank accorded to container structure is surprising at first glance; however, this important factor affects not only net aircraft payload and payload security but container costs as well. Area navigation and related developments improving airspace utilization can greatly increase the efficiency of all aircraft. Aircraft structure, active controls, and engine technology advances as funded under current programs may be emphasizing engineering efficiency at the expense of either initial or increased maintenance costs. Similarly, the emphasis on fuel efficiency may result in increasing engine maintenance costs. Such trade offs between efficiencies and maintenance should be the subjects of continuing studies. Two examples of all-cargo interior design have been previously presented, the low-pressure eliptical fuselage and the spanloader. Unfortunately, some interior concepts tend to increase acquisition costs that adversely affect direct operating costs. In-transit control, based on the computer and automation state of the art, may provide significant benefits for the entire transportation industry. The benefits to air cargo are not unique.

Improved block time can directly improve the quality of service in many instances; however, there may be an adverse effect in the form of higher fuel costs if reduced block time is achieved by higher cruise speed. The efficiencies of the dedicated as opposed to a conventional air freighter have already been discussed as has terminal automation. Improved door-to-door delivery time may result in lower realized payload fractions leading to higher unit costs. However, delivery time is a primary product of the industry and should not be degraded. The hub-spoke concept, while providing

higher payloads and encouraging the use of larger more efficient aircraft along dense routes, may have deleterious side effects at the periphery of the air cargo system and on the ground. Multistop systems trade increased payload at the expense of less efficient use of fuel and air crews. In addition, acquisition costs may rise significantly to reflect the need for more complex loading systems. Remote terminals, while highly efficient, can have adverse effects upon the quality of service. Joint loading concepts conserve terminals but potentially can affect delivery time.

The dedicated air cargo fleet, with or without an uncompromised all-cargo aircraft, has evolved as the preferred operational mode. Specialized carriers exploiting specific markets have simplified operations but this simplification can occur at the expense of flexibility and consequently vulnerability to cyclic and economic trend fluctuations. Joint rates covering both ground and air movement can increase the volume of air cargo market and, applied selectively, can then be applied in loading containers to increase average on-board density. A presealed or shipper-packed container system appears essential to the future development of the air cargo industry. Joint use of terminals is attractive where possible. Intermodal container capability are a requirement for the 1990 fleet even though it has some disadvantageous side effects.

Section 11

POTENTIAL MARKET DEMAND FOR NEW AIRCRAFT

The future air cargo fleet will match the growing demand for air transport with efficient, economical aircraft. The composition of this fleet and the required technologies to build the aircraft are subjects of this study. The growth of the air cargo industry has been accelerated with the availability of military surplus aircraft followed by derivatives of large passenger aircraft. The present fleet consists of some propeller-type transports plus a large number of jet aircraft. The future cargo aircraft fleets are expected to include derivatives of current production aircraft plus some new configurations.

The analysis of future demand was conducted within an operational scenario. This scenario included a definition of the future air cargo market, an operational simulation network and demand model, and a computerized mathematical simulation program for evaluation of various candidate aircraft as parts of the future fleet.

The simulation analyses incorporated the physical characteristics of aircraft and a specific format that included operational and simulation guidelines. The fleet evaluation process considered three general types of cargo fleets. The first fleet being made up of contemporary production aircraft, the second fleet contained these contemporary aircraft plus their future derivatives of the 1985 time period, and the last fleet contained the contemporary and derivatives plus new configurations of the 1990s decade. Each of these various fleet compositions was evaluated against the forecast market demand to the year 1990. The viability of conceptual aircraft, circa 1990, was evaluated in terms of potential new aircraft programs.

The final topic in this section presents the analysis of a change in the pattern of air service. This involved extension and elaboration of the hub-spoke concept utilizing a major airport as the hub, with a route network radiating out to smaller cities and airports. Typical traffic flow was from

a secondary airport to a hub, then to another secondary or to another hub, and then to the final secondary airport. Integration of a number of the hub airports by interconnecting routes creates an enlarged hub-spoke network. The analysis presented considers the relation between interhub flow and the size and operational characteristics of the servicing aircraft.

Operational Scenario

An operational scenario was prepared for the evaluation of market demand for new aircraft. The major elements in this scenario were a definition of the air cargo market, a framework for study consisting of a network of city-pairs and a demand model within this network. The demand model consisted of the forecast total revenue tonne-kilometers and a minimum number of flights per week.

Market definition. - Section 2 presented a projected growth of demand for the United States domestic and international air cargo markets and for the foreign air cargo market. These three market sections were analyzed independently utilizing the revenue tonne-kilometer demand data for the Baseline Scenario 2 (Section 2) for each of the three markets.

Network characteristics and demand models. - The network characteristics for each of the three markets were derived from the Official Airlines Guide (OAG) published by the Reuben H. Donnelley Corporation of Chicago, Illinois. This publication lists all scheduled airline service between city-pairs with the type of aircraft used. The data were taken from a computer tape with information for the month of August 1977. This set of data was annualized to represent all of 1977, the base year in the analysis. Additional machine processing of the data created an all-cargo aircraft network model containing the following for each of the three markets:

- City-pair routes aggregated into range classes in 160.9 kilometers (100 statute miles) class intervals
- Types of aircraft with total cargo tonnage capacity scheduled on each city-pair and aggregated into range classes

- Number of flights per week converted into flights per day and per year for each range class

U.S. domestic air cargo market network: A total of 114 city-pairs comprised the air cargo network in 1977. The shortest range flown was 151 kilometers (94 miles) and the longest was 4565 kilometers (2837 miles). These 114 city-pairs were served by United States domestic airlines that offered scheduled cargo service totaling some 62 000 annual departures.

United States international air cargo network: There were 82 city-pairs in the United States international market; each included a United States airport for international service and a foreign airport. The shortest stage distance was 180 kilometers (112 miles), and the longest 8282 kilometers (5147 miles). A gross total of 13 000 departures per year was scheduled in the total network.

Foreign air cargo market network: Interrogation of the international OAG data tape generated a total of 634 city-pairs included in the foreign market. The shortest distance flown was 96.5 kilometers (60 miles), and the longest was 9784 kilometers (6081 miles). In the total network, 161,000 departures were scheduled in the year 1977.

United States domestic air cargo demand model: The basic demand for the United States domestic market was distributed in accordance with the scheduled capacity as derived from the OAG. The forecast cargo flows of Section 2 include all anticipated flow whether carried on the main-deck or in the belly and encompass both all-cargo or passenger airlines. Civil Aeronautics Board (CAB) data for 1976 indicated that about 57 percent to total air cargo moved on all-cargo carriers. This percentage was applied to the network traffic to establish the base year traffic demand and resulted in a domestic market of 2557 million revenue tonne-kilometers for the year 1977 for all cargo. This same 57-percent factor was subsequently applied to each year out to 1991.

The 114 city-pairs in the domestic network were aggregated into 65 range-class elements. Each element contained the total number of flights scheduled for 1977 and a total amount of revenue tonne-kilometers to be carried on those

flights. The demand model preserved these range-class elements and flight frequencies over the years considered. The level of revenue tonne-kilometers increased each year as indicated by the demand forecasts in Section 2.

U.S. international air cargo demand: This model was similar to the domestic model, differing only in the value of the considered parameters. The 82 city-pairs were aggregated into 58 range-class elements, and the level of demand for 1977 was 1861 million revenue tonne-kilometers, growing to 5531 million in 1991.

Foreign air cargo demand model: The same assumptions as used for the United States markets were applied to the foreign market. The 634 city-pairs were aggregated into 224 range-class elements. The 1977 traffic demand level was 6093 million revenue tonne-kilometers, growing to a forecasted level of 34 278 million in 1991.

Scheduled air cargo capacity versus range: Data from a representative sample of United States cargo airlines are presented in Section 4. These data, Figure 4-2, show the cumulative distribution of air cargo with stage lengths for domestic carriers. The average stage length increased from 2200 kilometers in 1969 to about 2835 kilometers in 1976.

The OAG data used to develop the operational simulation network also contained 1977 values for offered capacity and range. These data are plotted in Figure 11-1. The scheduled capacity represents all United States domestic and international air cargo carriers while the encompassed foreign operators represent more than 95 percent of foreign scheduled air cargo service. The cumulative curves represent the various shares of the total scheduled capacity for each of the three study markets. The maximum range flown in the United States international schedule is 8282 kilometers with a weighted average stage length of 3485 kilometers. Equivalent data for the United States domestic air cargo market reveals a maximum stage length of 4565 kilometers with an average of 1729 kilometers. In the foreign market, the maximum range scheduled is 9781 kilometers with an average scheduled stage length of 2433 kilometers.

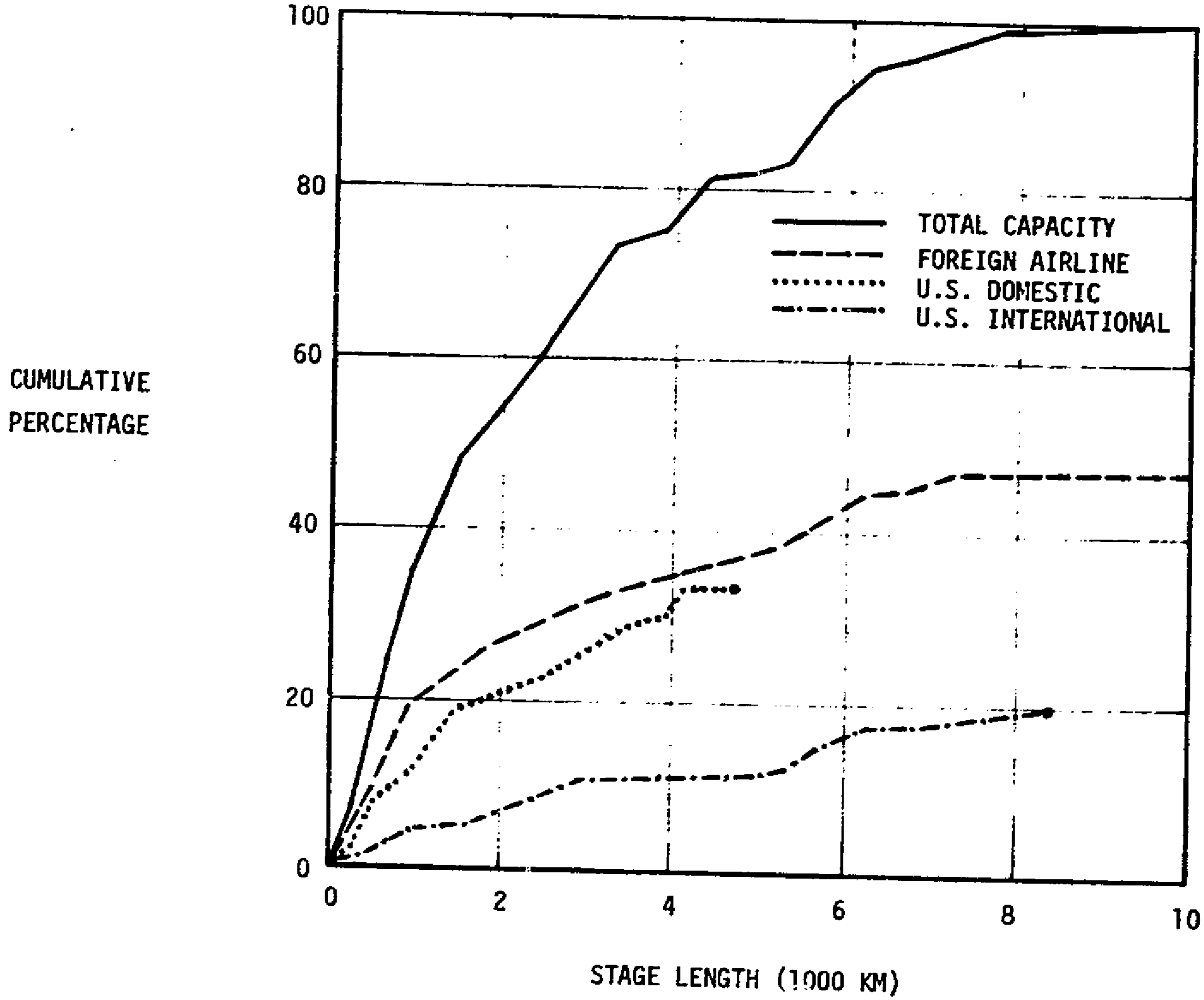

Figure 11-1. Scheduled Cargo Capacity vs Range, U.S. and Foreign Airlines

Referring to the data of Section 4, it is seen that the average stage length for the cargo carried, 2835 kilometers, is considerably greater than the average length for the capacity offered, 1729 kilometers. These results indicate that much of the capacity offered at the short stage lengths goes unused. A similar comparison cannot be drawn for United States international operations because the data of Section 4 are for range not stage length.

Operational simulation technique. - A proprietary Douglas Aircraft Company program was used to evaluate aircraft performance for each of the three air cargo markets. The model is mathematically deterministic and computerized. Data input to the program consisted of the market network and demand descriptors discussed in the preceding text. Each aircraft analyzed was defined by descriptive characteristics such as design range, payload versus range, and the payload at maximum takeoff gross weight. The purchase price or investment value was another input. Slope-intercept equations were input to represent functions for block time, trip cost, and fuel consumption - all as a function of the range flown. A target load factor for aircraft operations was also included.

An inventory of aircraft to be evaluated was input along with the respective characteristic values. The operational simulation program tested each of these aircraft as a candidate for each range-class element in the demand model considering the minimum cost of satisfying the demand in terms of the annual revenue tonne-kilometers, the range to be flown, the total number of flights at the target payload factor, and the trip costs generated in meeting the demand. The aircraft that provided the lowest total trip cost for each element was selected. A summary of the results for each element of the total market resulted in a composite fleet of aircraft. Results of these analyses provided the number and types of aircraft; total revenue generated; total operating expense; operating income; an annual cash flow for the entire 15-year period; total fleet value; and a return on investment (ROI) after insurance, depreciation, and assumed income taxes.

Simulation Analyses

The input data for the simulation of air cargo flight operations consisted of the market and demand data as discussed plus the physical and economic

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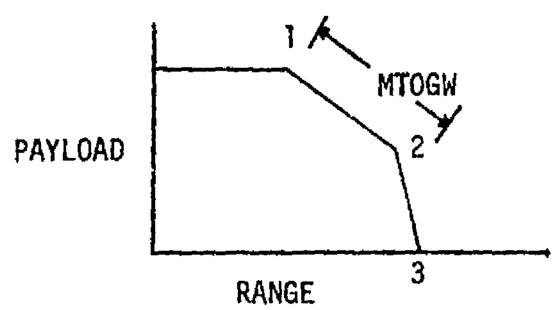
characteristics of the considered cargo aircraft. Certain constraints and operating assumptions were established to serve as simulation guidelines.

Characteristics of cargo aircraft: - The format of the three cargo markets was generated with data from aircraft currently operated by United States and foreign airline operators. These ranged from a Soviet Antonov AN-1 through various small to medium propeller-driven aircraft and turbine-powered jet aircraft to the largest, a B747 freighter aircraft. Lack of data restricted the fleet evaluation of contemporary aircraft to one turboprop plus several jet aircraft. For the derivative additions to the available aircraft inventory, a stretched turboprop aircraft was included along with several turbojet and turbofan aircraft derived from current production aircraft. Advanced cargo aircraft were configured from data previously generated during advanced engineering studies.

Contemporary cargo aircraft characteristics: These data generally were compiled by the Douglas Sales Engineering Department. Data for block time and block fuel consumption were derived from curves for each aircraft. A slope-intercept equation was used for these functions to simplify the input data format. The direct operating costs were expressed in terms of trip costs as a function of range. The following sketch shows a symbolic range-payload curve with two range values indicated.



The range at point 1 is the design range of the aircraft with the full, design, payload and required fuel plus reserves to fly that distance. Beyond point 1, added range may be flown by exchanging payload for added fuel. This is possible with the fuel tanks designed to accommodate the needed volume. At point 2, no more fuel can be added, thus extra range can be achieved only if the takeoff weight is reduced by reducing payload at the start of the flight. The maximum takeoff gross weight (MTOGW) thus occurs along the payload range curve at all

ranges between points 1 and 2. The payload at maximum range for MTOGW and the maximum range at MTOGW correspond to point 2. With no payload and a full fuel load, the aircraft could fly to the maximum range indicated as point 3. This payload range sketch applies to all aircraft considered in this study such as the contemporary aircraft presented in Table 11-1.

Derivative cargo aircraft characteristics: Data used to evaluate derivative cargo aircraft are listed in Table 11-2. The aircraft identities and related derivatives are listed below:

Contemporary Cargo Aircraft	Derivative Aircraft Model
DC-10-30	DC-10-CD
B747	B747-CD
DC-9-80	DC-9-CD
L-100	L-100
DC-X-200 (A)	DC-X-A
DC-X-200 (B)	DC-X-B

The first four aircraft in this tabulation are derived from the designated configurations. The derivations consist of stretching the fuselage and incorporating more efficient engines and aerodynamic improvements. The last two aircraft are conceptual configurations with basic DC-10 fuselage components. A new wing, improved engines, and other new components complete the conceptual cargo versions of the DC-X- A and B derivative cargo aircraft.

Advanced aircraft characteristics: Several advanced aircraft configurations were considered as future cargo concepts. All of these conceptual models were generated in various military and/or civil transport studies or other preliminary studies of new cargo aircraft. Table 11-3 presents the essential data used in the operational evaluation. All of these are 1990 advanced technology concepts that could be production versions for initial service in 1995.

The characteristic data for each of these aircraft fall into three general categories. The civil/military aircraft were derived as point design aircraft following military design philosophies. The low pressure freighter was designed with a conservative commercial philosophy. Each of these two classes was priced

TABLE 11-1

CONTEMPORARY AIRCRAFT CHARACTERISTICS

Descriptors	Aircraft Identity							
	L-100-30	DC-9-33F	B737-200C	B727-100C	B707-320C	DC-8-63F	DC-10-30AF	B747-200F
Design Range (km)	2871	1370	1778	2426	4723	3982	5741	4630
Design Payload (kg)	23 174	17 687	15 872	18 866	42 629	52 152	81 630	118 137
MTOGW (kg)	70 307	51 700	53 060	76 642	151 470	160 993	259 402	355 998
Payload at Maximum Range for MTOGW (kg)	15 872	15 419	10 430	5 714	14 966	21 314	48 978	49 885
Maximum Range at MTOGW (km)	5371	2148	3574	4408	9445	8890	9816	10 556
Block Time Function (hr at R km)	0.40+ 0.00180xR	0.40+ 0.00124xR	0.35+ 0.00129xR	0.50+ 0.00119xR	0.378+ 0.00117xR	0.40+ 0.00119xR	0.421+ 0.00114xR	0.379+ 0.00111xR
Block Fuel Function (kg at R km)	1134+ 3.465xR	907+ 3.349xR	1360+ 3.093xR	1814+ 4.187xR	2721+ 6.908xR	4535+ 7.109xR	3628+ 9.595xR	10 884+ 12.244xR
Investment Value ($ Million)	5.4	9.0	9.5	12.5	15.0	11.0	35.5	40.9
Trip Cost U.S. ($ at R km)	562+ 1.168xR	570+ 1.024xR	543+ 1.039xR	828+ 1.140xR	1205+ 1.462x2	1502+ 1.535xR	2015+ 1.896xR	4018+ 2.764xR
Trip Cost Foreign ($ at R km)	591+ 1.285xR	600+ 1.134xR	587+ 1.141xR	845+ 1.305xR	1296+ 1.688xR	1652+ 1.769xR	2130+ 2.213xR	4374+ 3.167xR

TABLE 11-2

DERIVATIVE AIRCRAFT CHARACTERISTICS

Descriptors	Aircraft Identity					
	DC-10-CD	B747-CD	DC-9-CD	L-100	DC-X-A	DC-X-B
Design Range (km)	6019	5371	1296	2778	2259	4667
Design Payload (kg)	81 630	110 108	22 222	27 210	41 631	41 450
MTOGW (kg)	245 797	362 800	63 490	77 095	132 876	149 655
Payload at Maximum Range for MTOGW (kg)	44 443	56 688	13 786	21 541	24 036	39 228
Maximum Range at MTOGW (km)	10 742	10 279	4 000	4 741	5 963	4 926
Block Fuel Function (kg at R km)	5442+ 8.7664xR	4535+ 13.153xR	1784+ 3.0690xR	2268+ 3.6404xR	922+ 5.4452xR	429+ 5.7207xR
Investment Value ($ Million)	35.7	43.3	13.0	9.289	24.0	24.228
Trip Cost U.S. ($ at R km)	1814+ 1.9363xR	1814+ 2.7556xR	404+ 1.134xR	756+ 1.2507xR	1108+ 1.2138xR	749+ 1.3252xR
Trip Cost Foreign ($ at R km)	1993+ 2.2247xR	1993+ 3.1887xR	451+ 1.2271xR	871+ 1.3704xR	1222+ 1.3270xR	763+ 1.5133xR

TABLE 11-3

ADVANCED AIRCRAFT CHARACTERISTICS

Descriptors	Aircraft Identity						
	Civil/Military Cargo			CLP	Dedicated Cargo, Spanloader		
	CMS Small	CMM Medium	CML Large	Civil,Cargo, Low Press.	SLS Small	SLM Medium	SLL Large
Design Range (km)	6667	6667	6667	6852	6667	6667	6667
Design Payload (kg)	58 955	117 910	176 865	154 190	317 200	475 268	634 900
MTOGW (kg)	231 557	377 766	591 364	400 440	754 171	1 077 970	1 364 582
Payload at Maximum Range for MTOGW (kg)	20 048	79 362	136 050	99 770	37 641	174 598	300 217
Maximum Range at MTOGW (km)	10 000	10 000	10 000	11 112	18 520	18 520	18 520
Block Time Function (hr at R km)	0.417+ 0.00117XR	0.417+ 0.00117XR	0.417+ 0.00117XR	0.40+ 0.00136XR	0.40+ 0.00120XR	0.40+ 0.00114XR	0.40+ 0.00114XR
Block Fuel Function (kg at R km)	3154+ 8.8811XR	4659+ 13.125XR	11 118+ 19.102XR	10 000+ 12.243XR	18 140+ 15.427XR	45 350+ 19.957XP	81 630+ 24.732XR
Investment Value ($ Million)	53.9	71.7	107.6	59.0	129.5	159.0	188.0
Trip Cost U.S. ($ at R km)	760+ 1.798XR	1033+ 2.443XR	1919+ 3.360XR	1069+ 2.840XR	2692+ 3.594XR	6006+ 4.531XR	104 80+ 5.584XR
Trip Cost Foreign ($ at R km)	864+ 2.068XR	1186+ 2.806XR	2285+ 3.888XR	1218+ 3.242XR	3288+ 4.101XR	7498+ 5.163XR	13167+ 6.394XR

primarily on the basis of manufacturing weight empty. The various spanloader aircraft data and estimated prices were drawn largely from existing studies by Boeing and Douglas. In all three cases, the various parameters represented a preliminary design philosophy to derive representative configuration characteristics.

It should be noted the civil/military configurations are considerably more costly in comparison with the low pressure freighter. The primary differences in design requirements accounting for this cost variation are illustrated in the following comparative table.

	Civil/Military	Low Pressure
Cruise Mach	0.80	0.72
Pressurization Differential	55 100 pascals (8 psi gage)	34 500 pascals (5 psi gage)
Floor	Military (heavy vehicles)	Commercial (containers)
Fuselage	Double Lobe Circular	Oval
Landing Gear	Kneeling	Standard
On, Off Load	Drive Through	Nose and Side doors
Air Drop	Yes	No
Tie-down Restraint	High G	Moderate G

All of these parameters substantially affect the empty operating weight (OWE) and hence the manufacturing cost of each aircraft.

A series of general arrangement sketches is included to illustrate a few of the aircraft considered in this operational simulation of air cargo fleets. A derivative aircraft is pictured in Figure 11-2. These aircraft, with essentially the same exterior envelope, are conceptual cargo versions of the Douglas Aircraft Company DC-X-200(A) and DC-X-200(B) concepts. Differences between the DC-X-A and DC-X-B are in the engines and range capability. The DC-X-B has a slightly lower gross payload with about twice the design range capability.

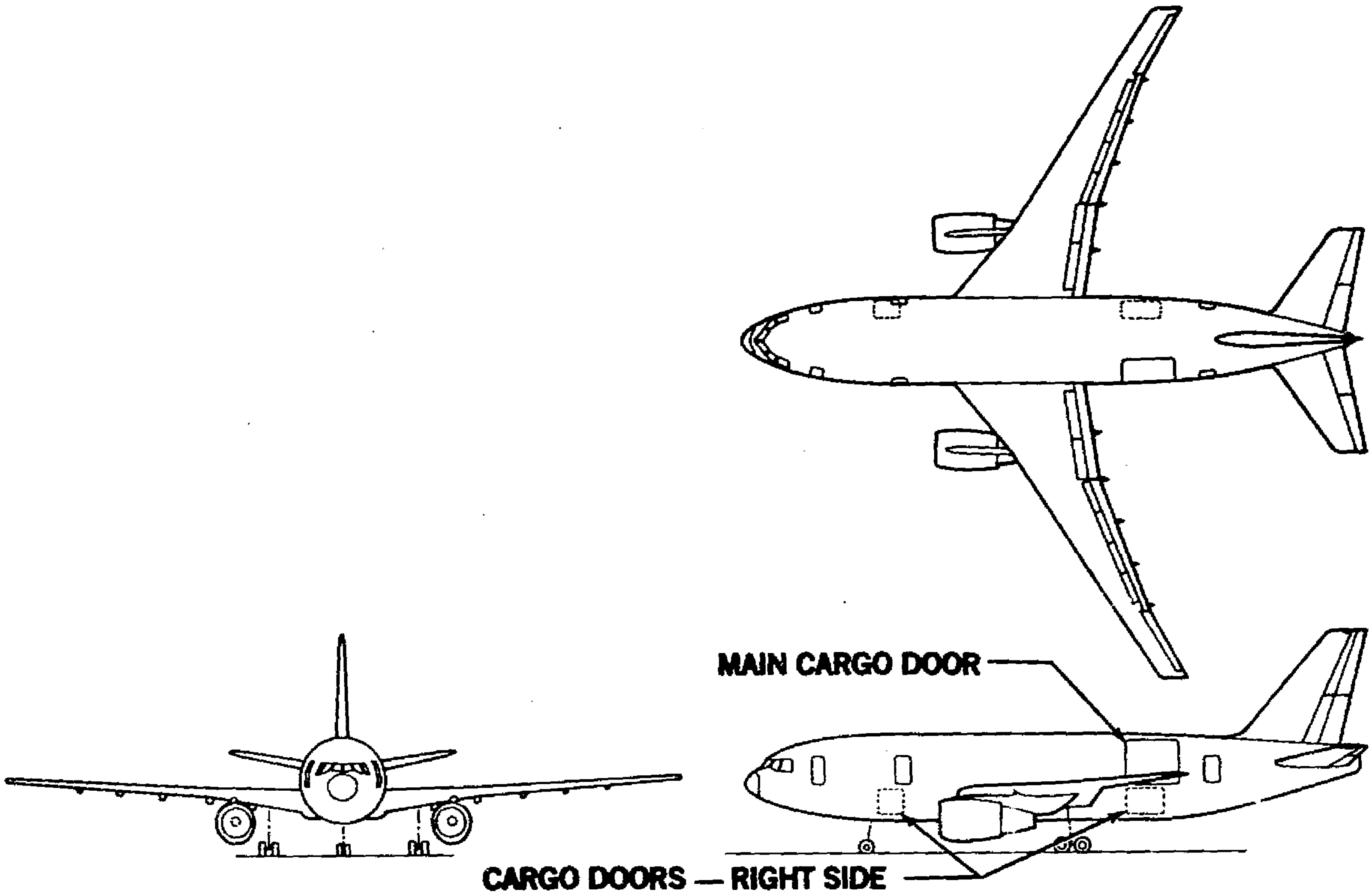


Figure 11-2. General Arrangement, Models DC-X-A and DC-X-B

The aircraft considered are twin-engine, low-wing configurations. The fuselages utilize sections from the DC-10 series of transport aircraft. Operating systems, furnishings, and engine pods also have a high degree of commonality approaching 90 percent. Although new wing and empennage components are required, many actuators and control elements are basic DC-10 parts. It is estimated that line replaceable items in the Models DC-X-A and DC-X-B have approximately a 91-percent commonality with the DC-10-30.

The preceding derivative approach to improved aircraft will be prevalent throughout the aircraft industry in the near future. The application of existing aircraft components in new configurations is an important factor in reducing development and production costs.

An example of an advanced concept freighter aircraft is depicted in Figure 11-3. This aircraft has a design range of 6667 kilometers at a payload of 58 955 kilograms. The aircraft is configured to military specifications with civil missions in mind. The potential advantage of this concept is in a commonality cost base between civil and military operators. Various design features are listed below:

- Nose loading with a clamshell section and an on-board loading ramp.
- Truck-bed floor height with the cargo floor designed for heavy motorized vehicles.
- A ceiling clearance of 4.1 meters to accommodate outsized equipment.
- Wide-body design to accept two rows of standard cargo containers of 2.4-x 2.4-x 6-meter (8-x 8-x 20-feet) for a total of 10 containers.
- A floor width of 5.3 meters.

- A cabin and cargo compartment pressurized to an equivalent altitude of 2438 meters (8000 feet).

- A supercritical, high-wing configuration with active control systems.
- Four fanjet engines with high by-pass ratios.

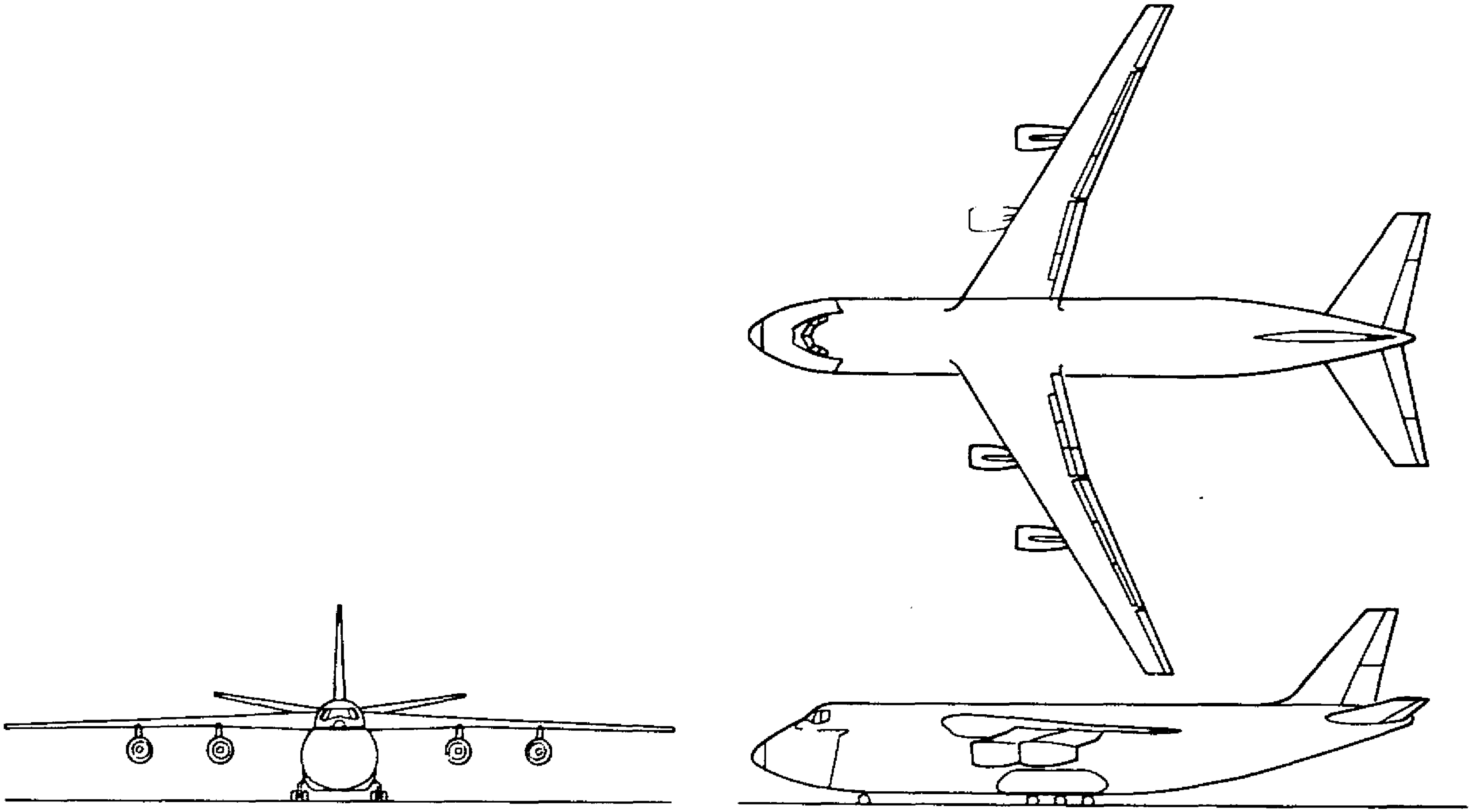


Figure 11-3. General Arrangement, Civil/Military, Small Cargo Aircraft (CMS)

- A landing gear system with footprint pressures compatible with standard military and commercial airports.
- Conventional takeoff and landing profiles for a runway of 2438 meters (8000 feet).

This model as depicted in Figure 11-3 is classified as the Civil/Military Cargo Aircraft, Small. The next two aircraft in this same series, Table 11-3, are of the same general configuration. Each is a four-engined aircraft. The Civil/Military, Medium is a scaled-up version with a lengthened fuselage, a larger wing and floor width of 5.3 meters to accommodate 14 standard cargo containers. Other physical features are the same in character as the small aircraft.

The Civil/Military, Large configuration is parametrically expanded from the first two versions. It differs in having a 7.7 meters floor width to accommodate three rows of containers. Range and performance characteristics are the same for all three aircraft. In appearance, the three aircraft are similar, differing only in dimensional characteristics required for the design payloads listed in Table 11-3. For convenience in nomenclature, the aircraft are coded as CMS, CMM, and CML in later sections of this report.

An example of a conceptual configuration for a dedicated civil freighter is shown in Figure 11-4. This model designated as CLP for the sake of brevity, is a large, low-wing aircraft with four fanjet engines. Notable characteristics of this aircraft are listed below:

- Nose loading with a clamshell section opening up for access to the main cargo deck.

- An oval, wide-body shape for three rows of standard cargo containers, 2.4- x 2.4- x 6-meters, totaling 20 in number.
- A pressurized cockpit and crew compartment.

- A cargo section pressurized to a maximum of 34 474 pascals (5 pounds per square inch gage) pressure differential. This precludes passengers and live animal cargo being carried outside of special containers.

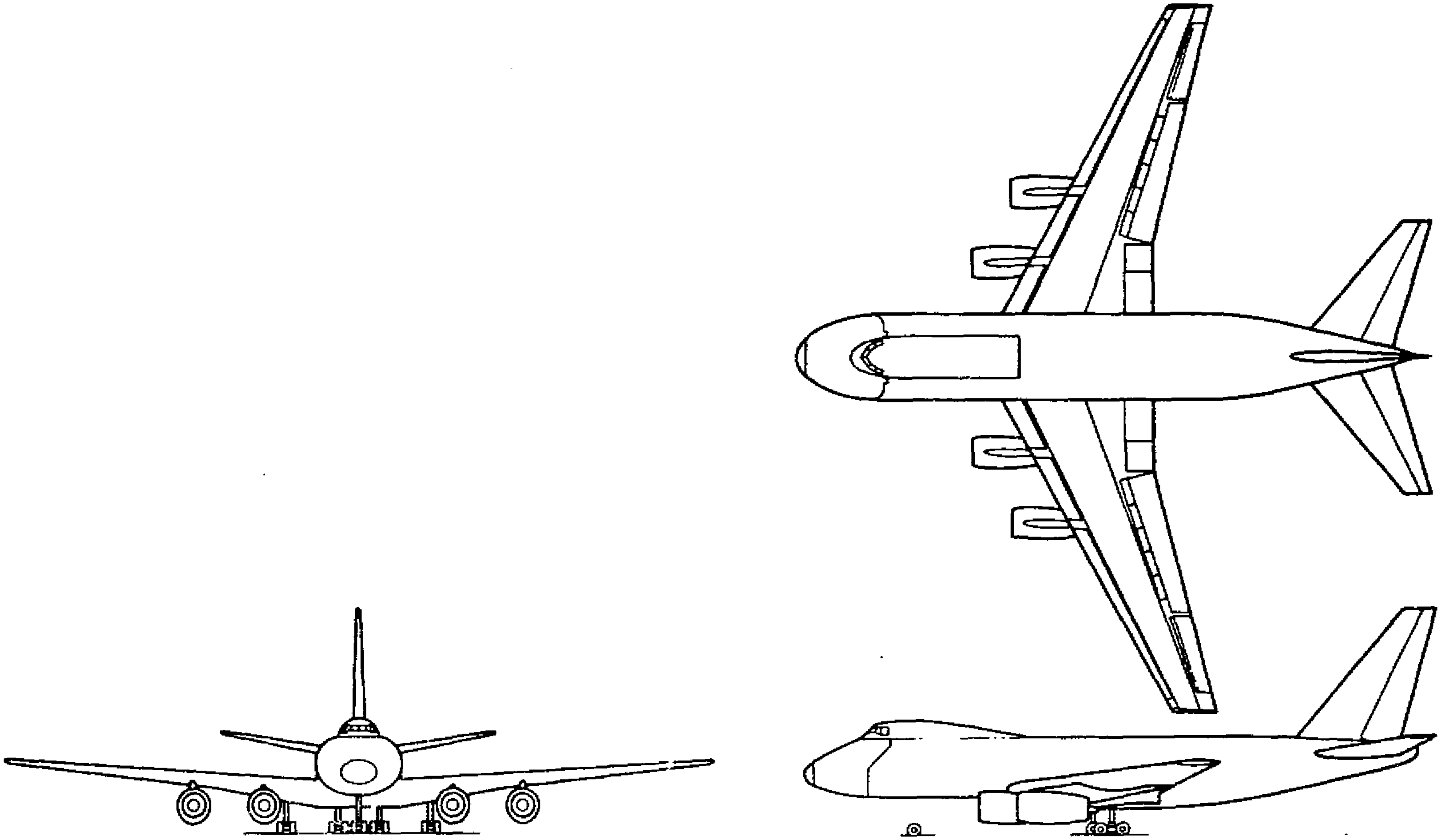


Figure 11-4. Dedicated Civil Cargo Aircraft, Low Pressure (CLP)

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- Compatibility with current (1978) airport runways, taxiways and parking aprongs, and terminal loading docks.

The large spanloader types of aircraft listed in Table 11-3 as small, medium and large are three versions of a conceptual aircraft reported in a Boeing Aircraft Company study for NAS, (Reference 10-1). The aircraft shown in Figure 11-5, Dedicated Cargo Spanloader, Small, is a six-engined swept-wing design similar to the Boeing concept. The crew is housed in a central pod which also contains the nose landing gear. The main landing gear trucks are contained in the center afterbody with supplementary gear contained in trailing-edge pods as shown. Vertical tee-tails are at the wing tips.

The cargo compartments are contained between the wing spars in a manner compatible with standard 2.4-x 2.4-meter containers of varying length. Loading is accomplished through openings in the wing tips with appropriate end closure doors, compartments are not pressurized. The small configuration, Figure 11-5, has two rows of container compartments while the medium and large versions have three or more rows.

All three versions of the spanloader are parameterized with the same general outline, varying only in size and number of engines. The medium and large spanloaders have eight engines each. For convenience in nomenclature, these aircraft are coded as SLS, SLM, and SLL where appropriate in text or figures.

Simulation format. - In the simulation process, certain ground rules and assumptions were adopted that quantified the study framework within the operational scenario. These ground rules were established for the market definition, aircraft characteristics, and the operational and economic fleet evaluation process.

Market ground rules: Certain assumptions were made in creating the market networks and demand models.

- The network is defined as the scheduled service on city-pairs listed in the August 1977 OAG, North American and International editions.

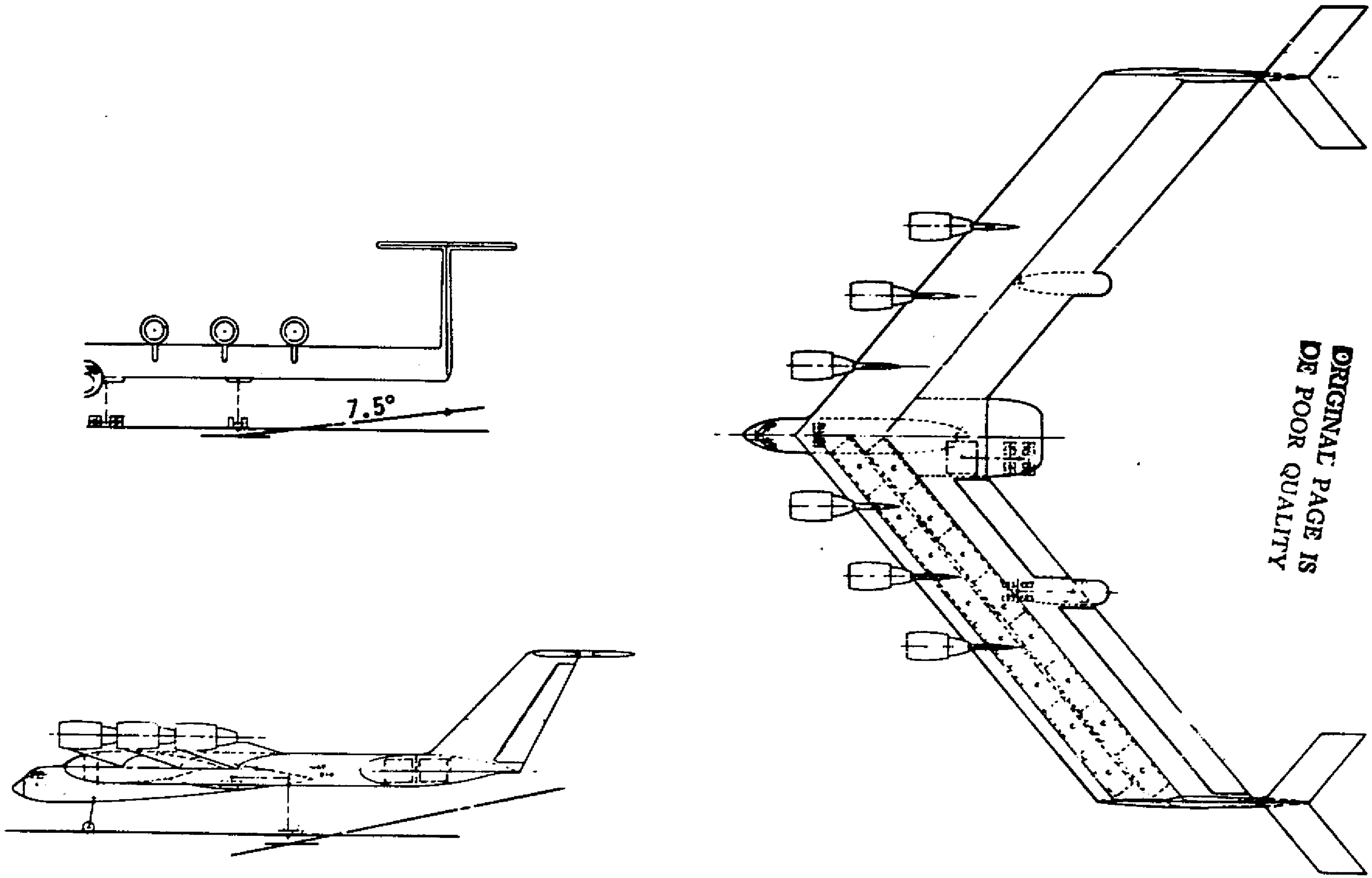

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Figure 11-5. Dedicated Cargo, Spanloader, Small (SLS)

- The distribution of revenue tonne-kilometer demand is proportional to the scheduled capacity on each city-pair as specified by equipment types in the base OAG with the total demand.
- Flight frequencies are set as equal to those in the base OAG, and all fleet solutions in years subsequent to 1977 are required to provide those frequencies as a minimum level.

Aircraft characteristics assumptions: The market networks were established by aggregating capacities from all-cargo aircraft operated by scheduled airlines. For input to the operational simulation, however, the contemporary fleet is limited to all-cargo aircraft currently in production with one exception. The DC-8-63F was included but limited to those that were in flight status with cargo carriers in the base year 1977. Current production types of all-cargo aircraft are listed in Table 11-1 along with the DC-8-63F. No limitation is placed on numbers of aircraft needed except for the DC-8-63F.

Operational and fleet economic evaluation rules: Each of the markets, U.S. domestic, U.S. international, and foreign, was analyzed as a separate operational concept. Eleven rules and assumptions were adopted for fleet operations.

- The city-pair network is held constant with no additions or deletions.
- The market demand distribution scheme is held constant for the entire period of 1977 through 1991.
- The simulation fleets for 1977 are equivalent to the actual contemporary fleet consisting of the aircraft listed in Table 11-4.
- Fleet aircraft payload factors are 0.64 for the year 1976 and are uniformly increased annually to a level of 0.70 by 1984 and are held constant thereafter to 1991.
- All economic data are inflated by 6 percent per annum through 1991.
- Economic results of fleet operations are discounted back to the base year and are expressed in base year 1977 dollars.

TABLE 11-4

CONTEMPORARY FLEET COMPOSITION

FOR BASE YEAR 1977

Aircraft Identity	Number in Market		
	U.S. Domestic	U.S. International	Foreign
L-100-30			5
DC-9-33F	1	1	10
B773-200C			11
B727-100C	7	2	12
B707-320C	15	15	44
DC-8-63F	18	18	18
DC-10-30AF			2
B747-200F	6	6	6
	47	42	108

- Aircraft direct operating costs (DOC) are computed utilizing the modified ATA method excluding the aircraft depreciation and insurance elements.
- A return on investment (ROI) index is computed with a discounted cash flow analysis to the base year 1977. This includes gross revenue plus fleet salvage value in 1991 less the sums of DOC, IOC, depreciation, insurance, and a tax level of 48 percent of net operating income.
- Cargo tariff rates for 1977 are $0.171 per tonne-kilometer for the U.S. international market, $0.2309 for the U.S. domestic market, and $0.2768 for the foreign market. These are representative average rates applied to all scheduled cargo.
- An indirect operating cost (IOC), used in computing operating income for the total fleet, is assumed at 41 percent of revenue for the foreign market and 48 percent of revenue for the U.S. domestic and international markets.
- Fuel costs are 35 cents per gallon (9.25 cents per liter) for the U.S. and 45 cents per gallon (11.89 cents per liter) for the foreign markets at 1977 levels.

All of these rules were adopted to provide a reasonably representative format for fleet evaluation. All economic values used were established as accurately as possible to represent a total composite structure of market and aircraft. Data sources typically were internal Douglas Aircraft Company departments and Civil Aeronautics Board documents. These were reviewed both by Douglas and Flying Tigers Line personnel.

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Fleet Evaluation Results

Results of each fleet evaluation are presented as the types of aircraft selected and the number of revenue tonne-kilometers carried by each type of aircraft. In all three markets, the first analysis included a fleet solution with contemporary aircraft. The second evaluation added derivative aircraft to the available inventory with the fleet composed of both contemporary and derivative types. For the third evaluation, advanced aircraft were added to the other two types as available inventory for the composite fleets.

Contemporary aircraft are available as needed in each year following 1977. Thus, the fleet expands to carry the traffic at the target fleet load factors. New derivative aircraft are made available in 1978. The rationale to introduction of a new model in 1978 is to assess the desired economic fleet mix as a minimum-cost operational solution to traffic requirements. From 1978 to 1991, the evaluation of the least-cost fleet mix reveals changes in fleet types as the demand grows from year to year. It is of primary interest to measure the changes in mix to ascertain how many new types of aircraft are required to exploit growth in demand. Similarly, the advanced concept aircraft also are introduced in the second model year, 1978. Realistic introductory dates are more likely to be 1980 to 1985 for derivative aircraft and 1990 for advanced-concept aircraft of the large sizes considered herein. Results of new model introductions will generate solutions analogous to those developed herein. The differences will be in fleet numbers proportional to market growth and following the dates of introduction.

It is important at this juncture to reemphasize the purpose of this operational simulation. The purpose is to evaluate the relative potential of the considered concepts to compete in the aircraft market on the basis of their operational and economic characteristics. The numbers generated for the various fleet combinations are relative numbers only and are not intended to predict what contemporary or derivative aircraft will be purchased for use in the next decade or two. Each econometric fleet illustrates the relative distribution and hence the relative economic and operational potential of the respective types of aircraft as determined within the specific ground rules of this study.

Contemporary cargo fleet. - For convenience in analysis, the available aircraft inventory for each of the markets consisted of the following jet aircraft:

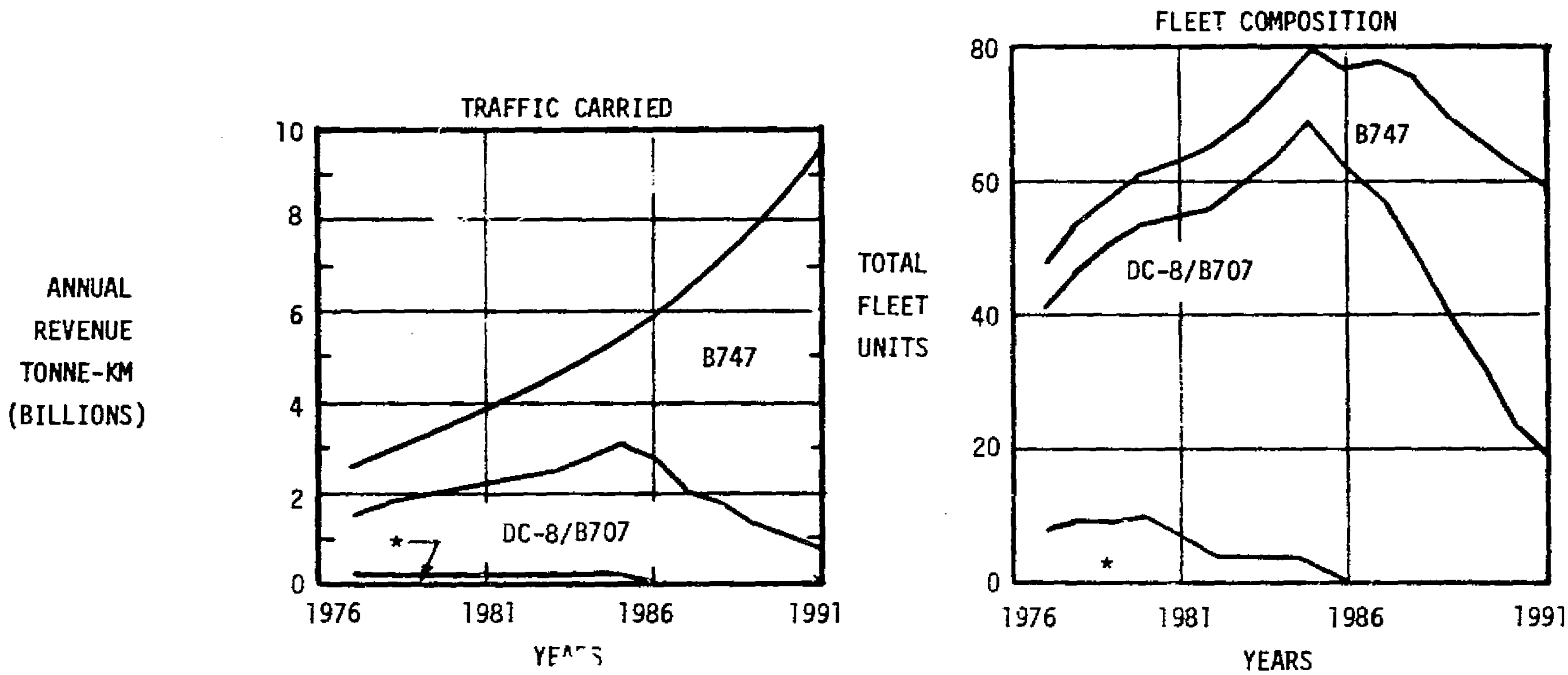
- U.S. domestic and international markets - DC-9, B707, and B747
- Foreign - DC-9, B727, B707, DC-8 and B747

In initial calibration runs with the simulation program, it was determined that the DC-9 was generally representative of aircraft below the size of the DC-8/B707 class. The evaluation of the contemporary fleet was not intended to differentiate fine points of performance between the various aircraft to select the "best" configuration. Rather, the intent was to determine the fleet composition by range and capacity of aircraft. Thus, the B707/DC-8 was represented by the B707 -320C. The B747-200F currently is the only aircraft in its size and range category.

The foreign market is a larger market than the U.S. markets. There are more and varied routes with a somewhat greater number of aircraft types. The addition of the DC-8 and B727-100C facilitated the initial calibration of the foreign market. This calibration was to achieve a first-year fleet solution generally comparable to those aircraft in actual service in 1977.

U.S. domestic contemporary air cargo fleet: Market demand and aircraft fleet evaluations for domestic air cargo market are presented in Figure 11-6. The all-cargo aircraft traffic carried in the domestic market grows from 2.554 billion revenue tonne-kilometers in 1977 to a total of 9.474 billion revenue tonne-kilometers in 1991. The fleet load factor achieved in 1977 was 64.75 percent, the desired target. The fleet total was 47 aircraft, consisting of eight DC-9 type, 33 B707 type, and six B747-200F cargo aircraft. These numbers reflected a least-cost econometric fleet mix to satisfy total cargo transport demand in 1977.

The fleet composition changes as the revenue tonne-kilometer demand expands as forecasted to 1991. To carry the traffic, a fleet of 24 B707 types and 38 B747 types of aircraft would be required in 1991 at a fleet load factor of 70 percent. Aircraft smaller than the DC-8/B707 in range and payload



*DC-9/B737/B727

Figure 11-6. U.S. Domestic Air Cargo Market, Contemporary Aircraft Evaluation

capacity are not selected by the fleet selection algorithm beyond the year 1985 in this particular market model. The DC-8/B707 type peaks out in numbers in 1984. Beyond that date, the B747 type provides the bulk of cargo transport.

U.S. international contemporary air cargo fleet: Figure 11-7 indicates the magnitude of traffic carried and fleet composition for the projected U.S. international air cargo market. The traffic carried is approximately two-thirds that of the domestic market. Traffic carried in 1977 was 1.861 billion tonne-kilometers with a fleet of one DC-9 type, five B707 types and seven B747 types of cargo aircraft. In 1991, the estimated traffic carried reaches a level of 5.947 billion revenue tonne-kilometers. The 1991 fleet, as shown, consists of 22 B747 class aircraft and one B707 class. The smaller DC-9 type drops out of the fleet mix in 1983.

Foreign contemporary air cargo fleet: The size of the market and fleet composition with contemporary aircraft only are indicated in Figure 11-8 for the foreign air cargo market. This market currently is the largest of the three markets studied. Traffic carried grows from 6.046 in 1977 to 38.751 billion revenue tonne-kilometers in 1991. Fleet composition is tabulated as follows:

	1977	1991
DC-9/B737	33	1
B727	20	7
DC-8/B707	73	117
B747	5	122

The dominance of the larger, more cost-effective aircraft is clearly revealed in the data. Note the marked increase in the B747 type after 1983.

A total fleet composition summary of contemporary aircraft in the all-cargo scheduled service for all three cargo markets is as follows:

	1977	1991
DC-9/B737	42	1
B727	20	7
DC-8/B707	111	142
B747	18	182

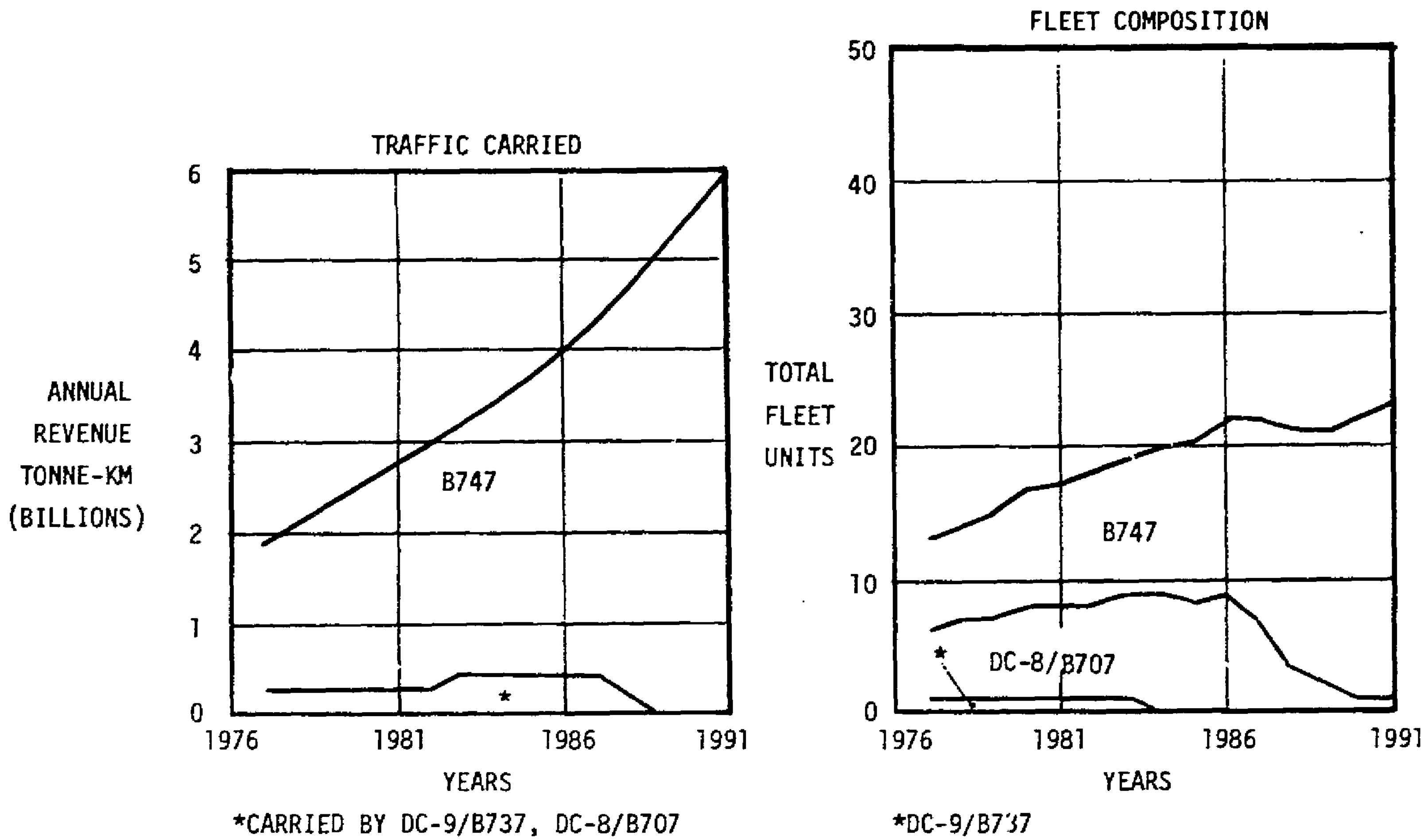


Figure 11-7. U.S. International Air Cargo Market
Contemporary Aircraft Evaluation

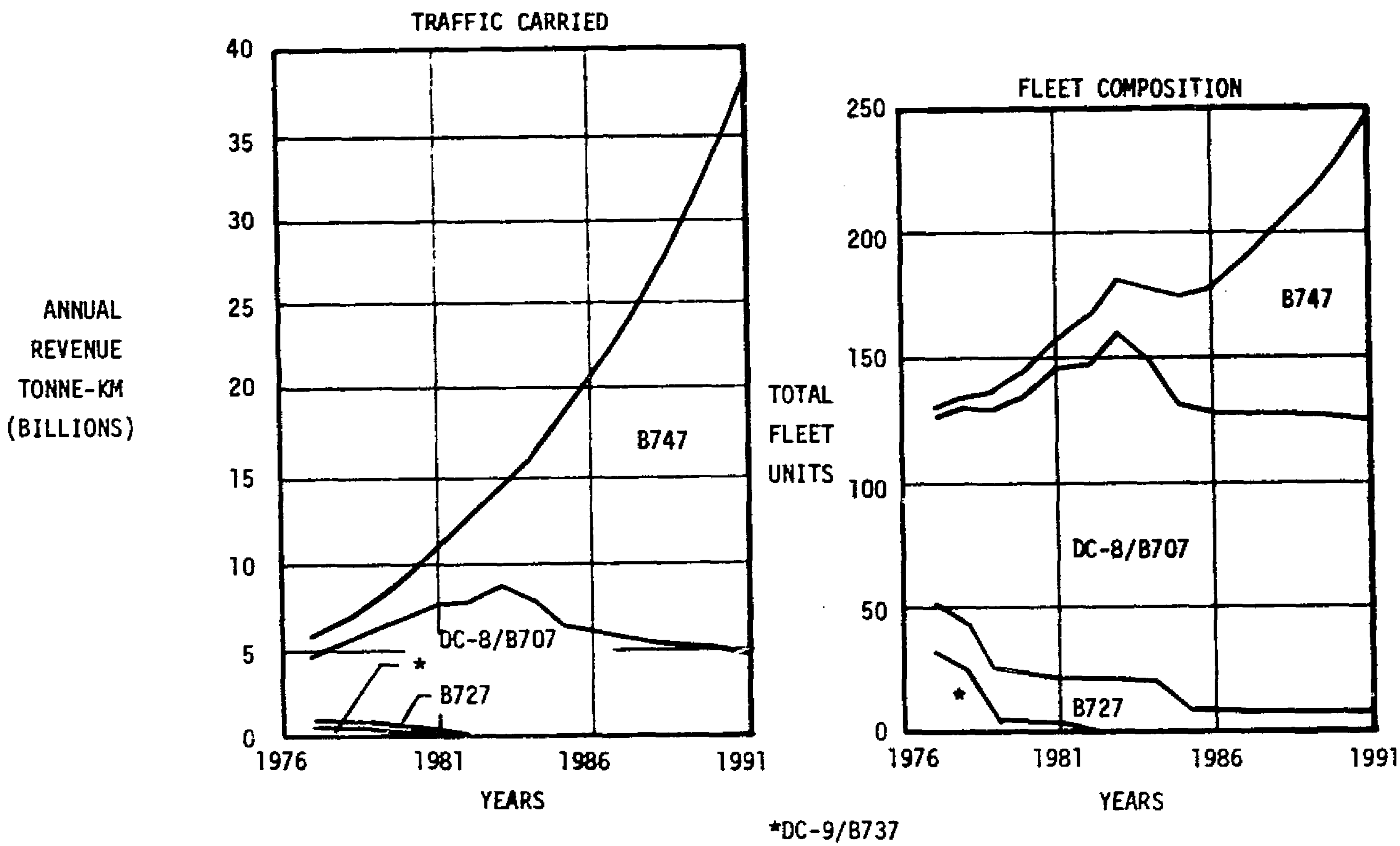


Figure 11-8. Foreign Air Cargo Market, Contemporary Aircraft Evaluation

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Contemporary and derivative cargo fleets. An evaluation was conducted with the fleet-available inventory consisting of contemporary aircraft plus derivatives. Each of the three market results is presented followed by a total fleet summary.

U.S. Domestic contemporary plus derivative air cargo fleet: Results of the fleet evaluation are shown in Figure 11-9. The total demand for revenue tonne-kilometers is the same as that shown in the contemporary fleet analysis. Aircraft DC-10-CD is a DC-10 cargo configuration. The DC-X-A and DC-X-B are conceptual DC-10 derivatives. As previously discussed the contemporary fleet consists of 47 of the DC-9, B707, and B747 types of aircraft in 1977. Following introduction of derivatives, the numbers of these contemporary aircraft decline steadily to zero in 1990. Derivatives selected in 1978 are the 9803, 1038, 2002, and 2003 aircraft. Also offered but not selected are the B747-300F and the L100-50D.

In the 1978 mix, the fleet consists of six DC-9, 32 DC-8/B707, and six B747, all contemporary types. In addition, the fleet contains two DC-9-CD, two DC-10-CD, two DC-X-A, and three DC-X-B derivative-class aircraft. The DC-9-CD generates 45.24 million revenue tonne-kilometers of traffic, some 1.5 percent of the total of 2983 millions. This amount in 1978 does not appear in Figure 11-9 because of the scale dimensions. In 1991, only two DC-9-CD aircraft are in the fleet, again too insignificant to be shown. The remaining fleet is made up of sixty DC-10-CD, fourteen DC-X-A and twenty-four DC-X-B types of aircraft.

U.S. international contemporary plus derivative air cargo fleet: The composition of the air cargo fleet in 1977 is the same contemporary fleet as shown before, 13 aircraft. With introduction of derivative models in 1978, the contemporary fleet becomes smaller each year, declining the zero in 1986. In 1978, the econometric fleet consists of three B707/DC-8 and six B747 types plus two DC-10-CD and one each of DC-9-CD, DC-X-A, and DC-X-B types of derivative models. By the year 1986, all contemporary aircraft disappear from the fleet. The total fleet in 1991 consists of 33 types DC-10-CD and one DC-9-CD, two DC-X-A, and nine DC-X-B types. These results are plotted in Figure 11-10.

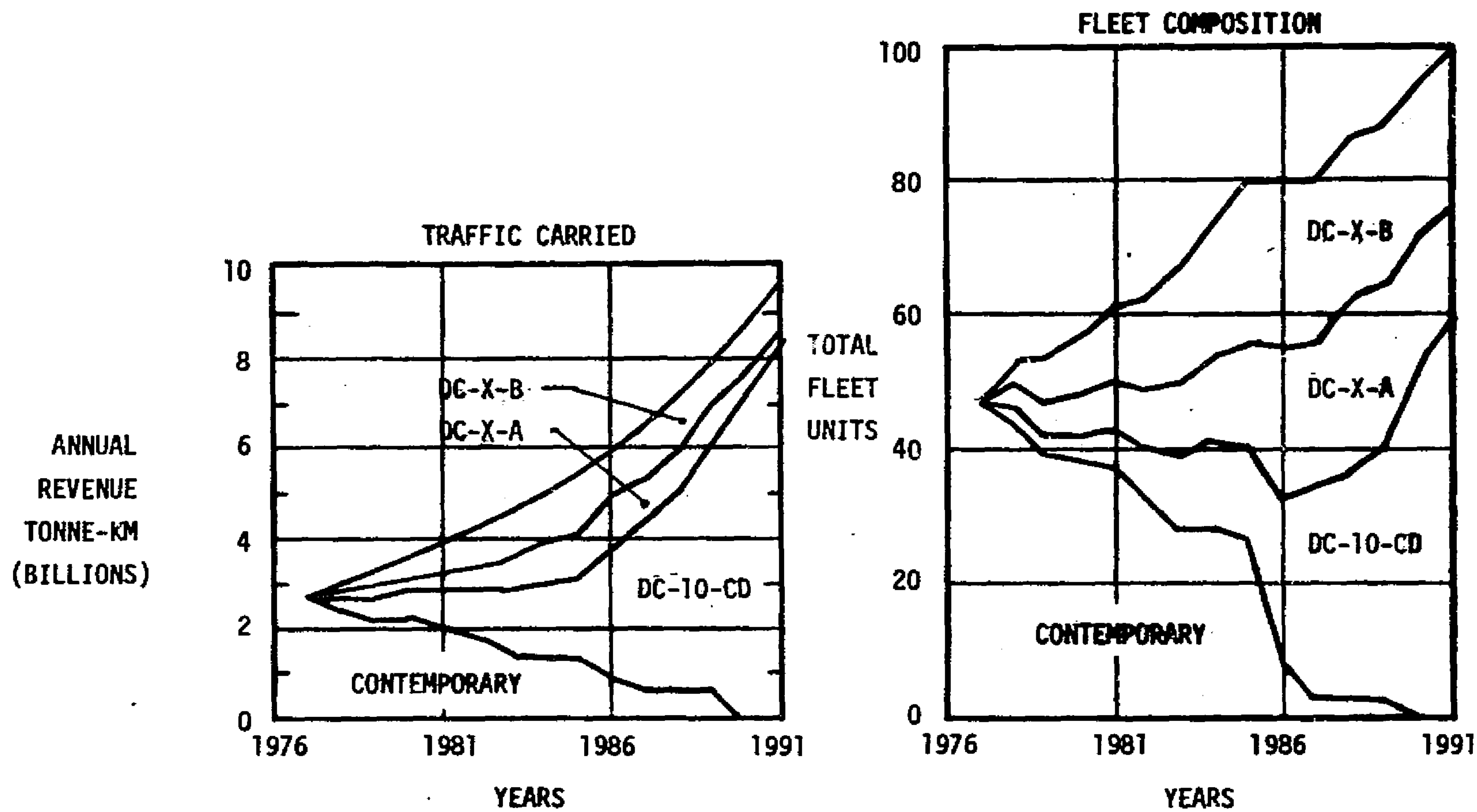


Figure 11-9. U.S. Domestic Air Cargo Market, Contemporary and Derivative Aircraft

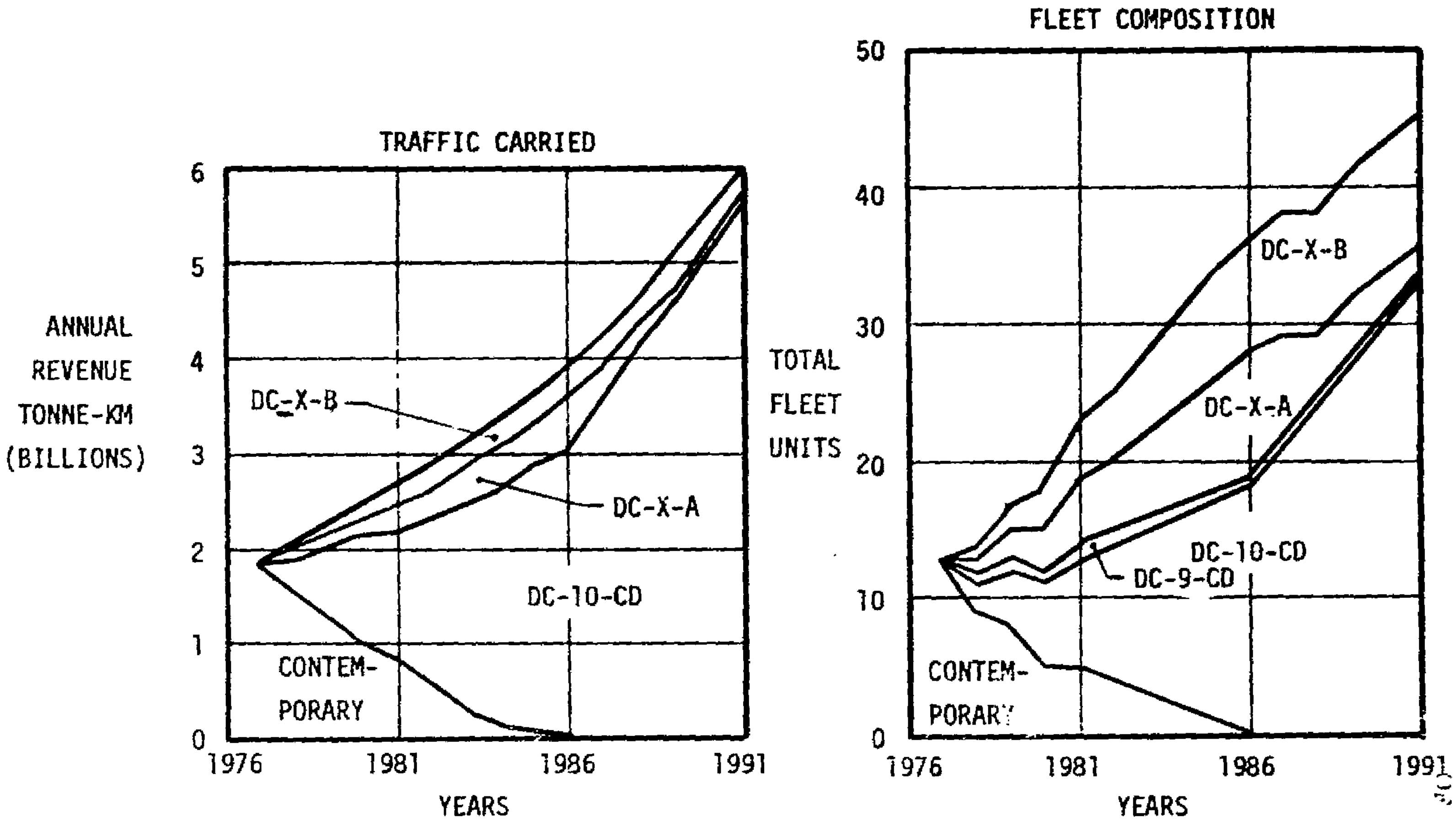


Figure 11-10. U.S. International Air Cargo Market, Contemporary and Derivative Aircraft

Foreign contemporary plus derivative air cargo fleet: In the larger foreign air cargo market, the fleet compositions shown in Figure 11-11 follow the same trends as in the U.S. markets. The dominance of the aircraft Model DC-10-CD shows in traffic carried and fleet numbers. The contemporary fleet of 1977 totaling 13 aircraft tapers out in 1989 with four units of the DC-8/B707 type retired in 1990. Following introduction in 1978, the derivative fleet is estimated to grow to 259 units of the DC-10-CD type, seven DC-9-CD, four DC-X-A and three DC-X-B transport configurations by the year 1991.

A summary of the resultant 1991 fleets for all three markets is presented in Table 11-5. The effect of introduction of derivatives in 1978 would be to drive contemporary aircraft out of the econometric mix. The derivatives selected have superior cost and payload characteristics which dominate the market as it expands from 1977 to 1991. Thus, in 1991, only derivatives appear in each fleet.

TABLE 11-5

DERIVATIVE FLEETS IN 1991

Aircraft Type	U.S. Markets		Foreign Market	Total
	Domestic	International		
DC-9-CD	2	1	7	10
DC-10-CD	60	33	259	352
DC-X-A	14	2	4	20
DC-X-B	24	9	3	36
	100	45	273	418

Contemporary, derivative and advanced air cargo fleets. - The final econometric fleet simulation exercise considered all three types of aircraft as available in 1977 and 1978. Each market solution is presented separately.

U.S. domestic contemporary, derivative, and advanced air cargo fleet: Fleet analysis results are presented in Figure 11-12. All three types of

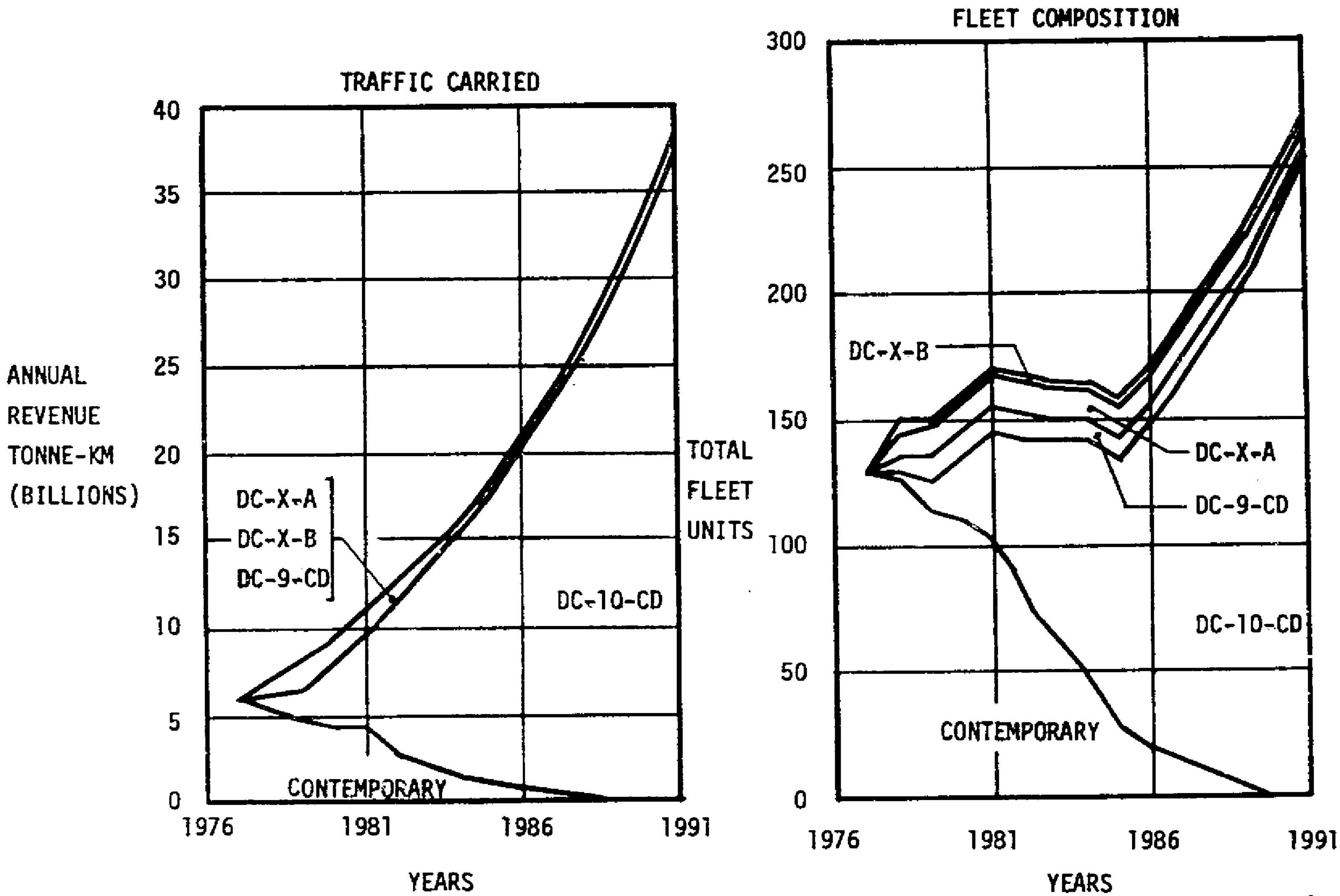
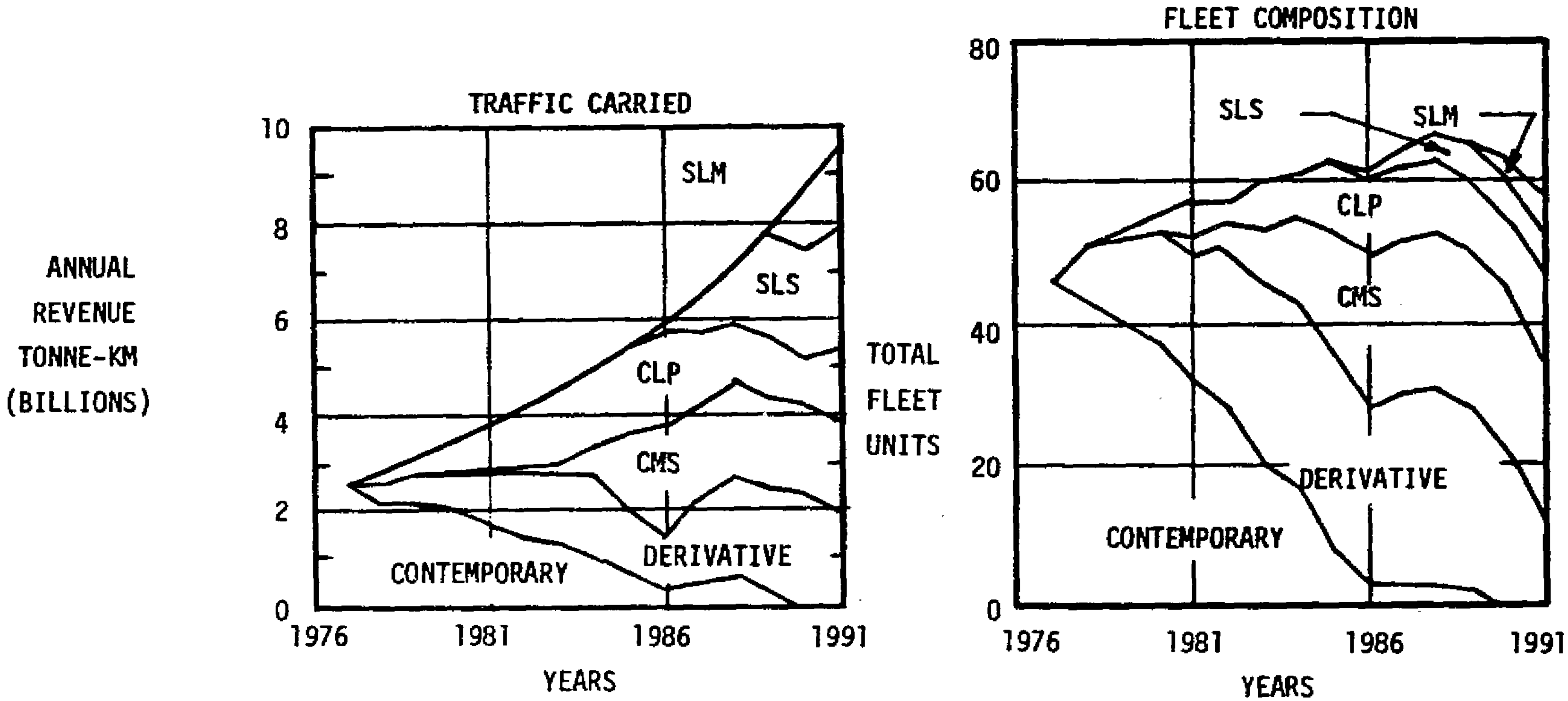


Figure 11-11. Foreign Air Cargo Market, Contemporary and Derivative Aircraft



CMS - Civil/Military, Small

CLP - Dedicated Civil Cargo, Low Pressure

SLS - Spanloader, Small

SLM - Spanloader, Medium

Figure 11-12. U.S. Domestic Air Cargo Market, Contemporary, Derivative and Advanced Aircraft

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aircraft were available for selection in the econometric fleet mix. In the first year, 1977, the fleet consisted of the contemporary aircraft only. In 1978, both derivative and advanced aircraft are available. The fleet in 1978 is composed of six DC-9 types, 32 DC-8/B707 types, five B707 types, one model DC-10-CD, two DC-9-CD types, two DC-X-A types, three DC-X-B types, and two vehicles of the CLP type. Another advanced aircraft, the CMS, enters the fleet mix in 1981. In 1986, the market grows to a level at which another advanced aircraft, the SLS, enters service. The last advanced aircraft, the SLM enters the fleet mix in 1990. The U.S. domestic fleet composition in 1991 is tabulated as follows:

Type	Number
DC-10-CD	13
DC-X-A	2
DC-X-B	8
Civil Military, Small (CMS)	15
Dedicated Civil Cargo, Low Pressure (CLP)	14
Spanloader, Small (SLS)	5
Spanloader, Medium (SLM)	5
Total	62

The domestic air cargo traffic carried in 1991 is estimated to be distributed as follows:

Type	Revenue Tonne-Kilometers (Billion)
DC-10-CD	1.998
DC-X-A	0.156
DC-X-B	0.446
CMS	1.303
CLP	1.502
SLS	2.337
SLM	1.732
Total	9.474

U.S. international contemporary, derivative, and advanced air cargo fleet: The U.S. international cargo market fleet composition is similar to the domestic fleet at about two-thirds of the traffic level. Figure 11-13 indicates the distribution of traffic and fleet composition by type. The contemporary fleet of 1977 is quickly displaced by both derivative and advanced aircraft following their introduction in 1978. Contemporary aircraft disappear from the econometric fleet after 1983. As the market expands, the larger advanced types of cargo aircraft displace most of the derivative aircraft. The Model CLP is the first advanced aircraft to enter the fleet. In 1984, the demand is sufficient to attract the CMS conceptual aircraft. The Model SLS would enter the market in 1986. The last aircraft to enter the forecasted market is the SLM model.

Although the total number of aircraft is small, the Model SLS would carry a large share of the traffic because of its size. The Model SLM is drawn into the econometric solution in 1990. Its contribution is insignificant in the last year of the market forecast period for the United States international market. The fleet mix for 1991 is tabulated as follows:

Type		Number
DC-10-CD		1
DC-X-B		1
CLP		9
SLS		7
SLM		1
	Total	19

The U.S. international air cargo carried in 1991 is estimated to be distributed by aircraft type as follows:

Type	Revenue Tonne-Kilometers (Billion)
DC-10-CD	0.196
DC-X-B	0.004
CLP	1.239

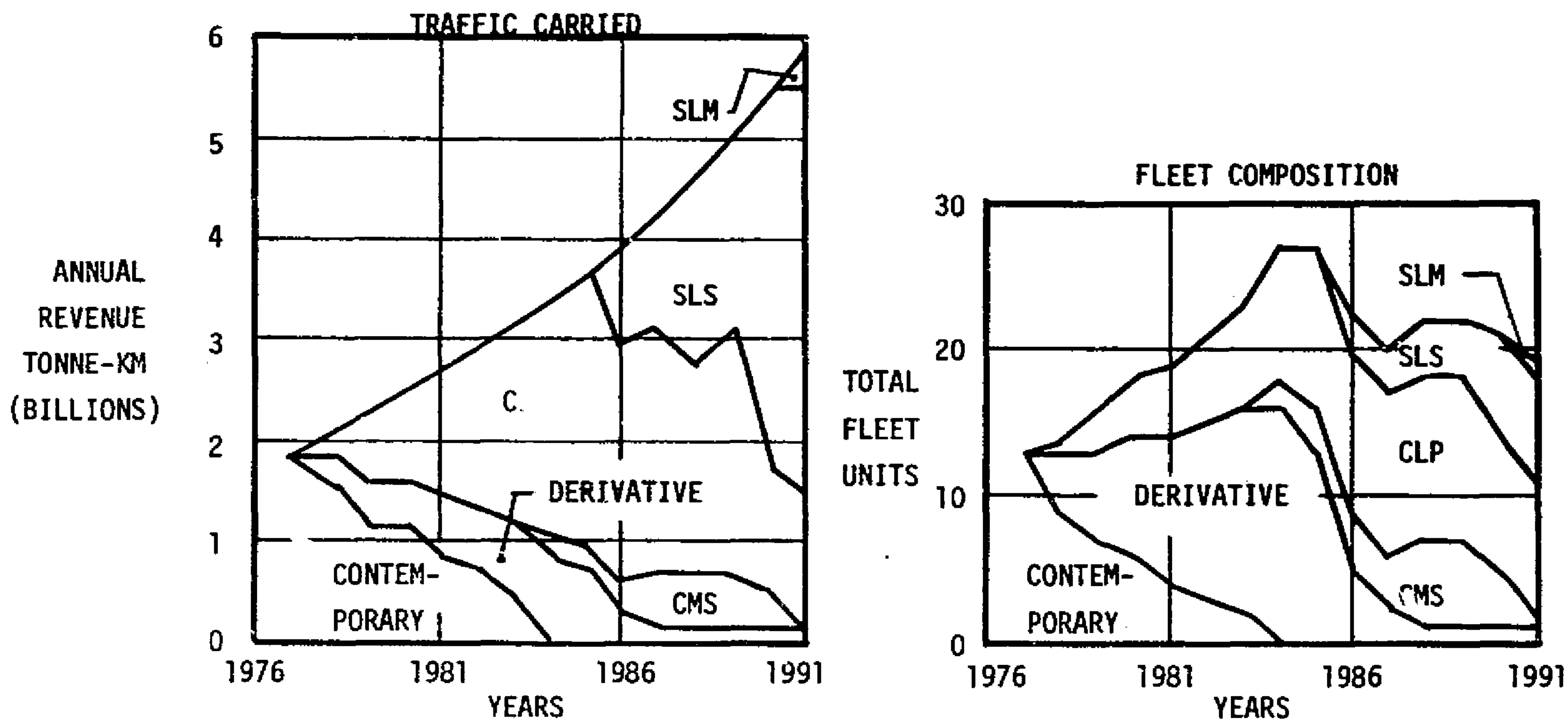

Figure 11-13. U.S. International Air Cargo Market, Contemporary, Derivative and Advanced Aircraft

Type	Revenue Tonne-Kilometers (Billion
SLS	4.133
SLM	0.425
Total	5.997

Foreign contemporary, derivative, and advanced air cargo fleet: The mix of aircraft predicted for the foreign air cargo market consisting of contemporary, derivative, and advanced aircraft is shown in Figure 11-14. With the larger forecasted total demand, the fleet mix follows the U.S. markets in general trends but with a larger fleet. For comparison, the derivative aircraft maintain a larger share of the estimated market than in either the U.S. international or domestic air cargo markets. Both the fleet of derivatives and the traffic carried are a larger fraction of the estimated total market than in the United States markets.

In the base year 1977, the econometric fleet consists of all contemporary aircraft. Following introduction of the derivative and new advanced aircraft in 1978, the number of contemporary aircraft tails off rapidly to zero in 1989. Derivative types become a part of the econometric fleet mix in their first introductory year. Because of the market structure that consists of a combination of range, revenue tonne-kilometer demand, and flight frequencies, the derivative fleet is estimated to dominate the market through 1986. Thereafter, numbers of advanced aircraft and their share of the market would reduce the derivatives fraction of the total market.

The first advanced configuration to become part of the fleet is the CLP model in 1979. The SLS model enters in 1983, with the SLM type starting in 1986. The 1991 fleet mix has no contemporary aircraft. Numbers and types of derivatives are 107 of the DC-10-CD (DC-10 derivative), and one DC-9-CD (DC-9-80F). The advanced concept aircraft consist of 59 of the CLP class, nine of the SLS class, and 10 of the SLM class.

The summary of the fleet composition in 1991 is included as Table 11-6. The summary includes all of the three markets studied.

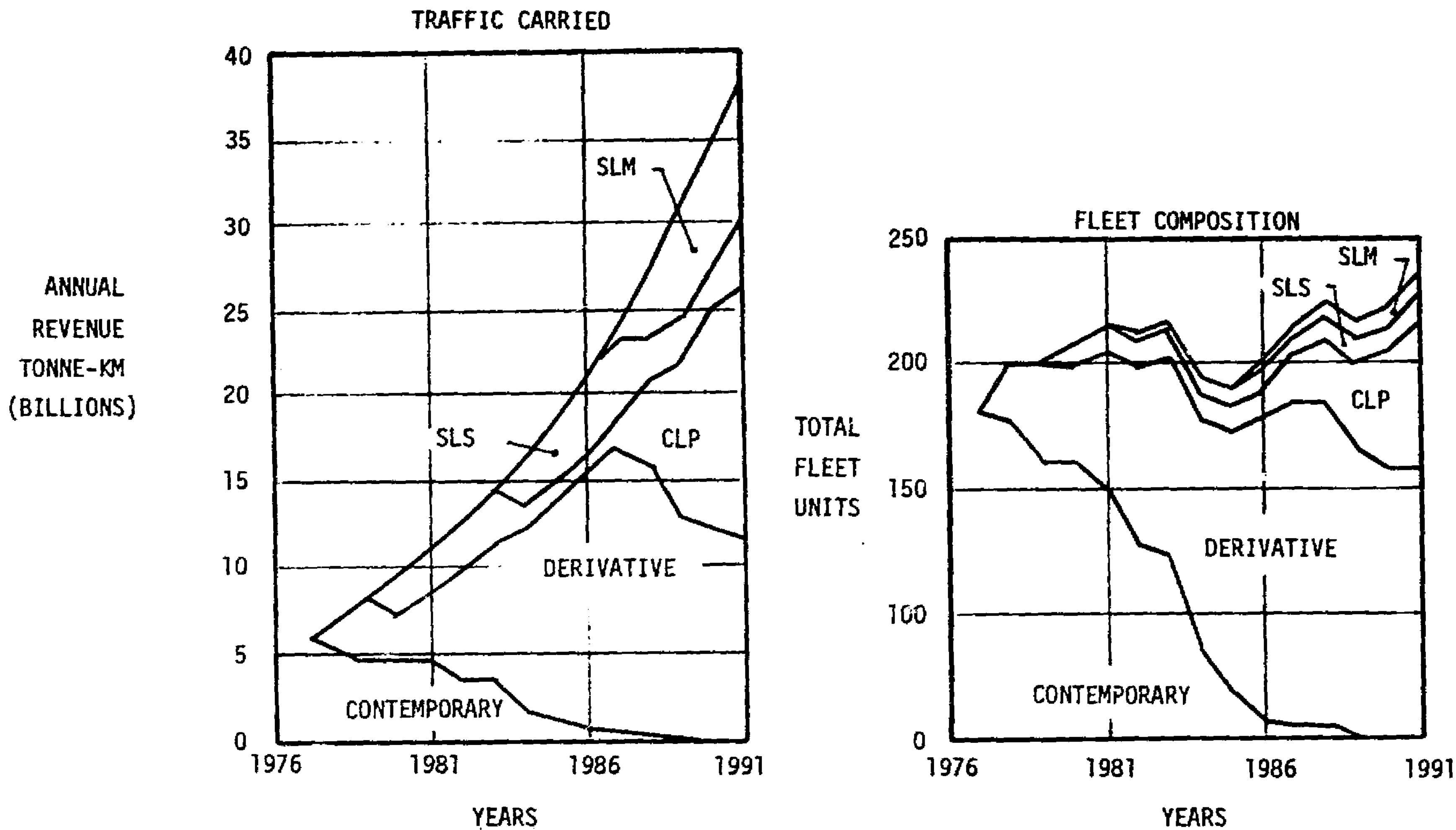

Figure 11-14. Foreign Air Cargo Market,
Contemporary, Derivative and Advanced Aircraft

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TABLE 11-6

DERIVATIVE PLUS ADVANCED CONCEPT AIRCRAFT FLEETS IN 1991

Aircraft Type	U.S. Markets		Foreign Market	Total
	Domestic	International		
Derivative				
DC-9-CD			1	1
DC-10-CD	13	1	107	121
DC-X-A	2			2
DC-X-B	8	1		9
Advanced				
CMS	15			15
CLP	14	9	59	82
SLS	5	7	9	21
SLM	5	1	10	16
	62	19	186	267

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Effect of reductions in minimum acquired frequencies of service. - One of the operational simulation ground rules was that each econometric fleet mix operate with at least a minimum level of flight frequencies. This level is equal to the flights scheduled on existing routes as specified in the August 1977 OAG for cargo aircraft. More flights could be required as traffic expands beyond 1977.

This basic ground rule tends to prevent a larger aircraft from being selected on a least-cost base to serve a particular route in comparison with a smaller, more expensive aircraft. To evaluate the effect of relaxing this minimum frequency requirement, the ground rule input to the machine simulation was reduced by 20 percent. The fleets were evaluated in each of the three markets to determine the effect of lower frequency requirements on the econometric fleet mix.

U.S. domestic fleet mix: A fleet mix is shown in Figure 11-15 for the domestic cargo market with a reduced minimum frequency of 20 percent below the 1977 level. Total fleet units in 1991 show derivatives and advanced concept aircraft with the contemporary dropping out in 1987. The contemporary fleet numbers are about the same as in Figure 11-12 with higher frequencies required. The retirement of the contemporary fleet occurs about 2 years earlier when frequencies are reduced. As might be expected, the role of the larger advanced aircraft is more prominent with fewer flights required. The distribution of aircraft sizes remains a function of the traffic demands on each route in the network. Thus, one size of aircraft will not dominate the market.

In comparing the fleet mix between Figures 11-12 and 11-15, note that the larger aircraft are required earlier in the time period as shown in Figure 11-15. Also, fleet numbers are smaller, with 11 DC-10 derivatives, nine Model CMS, 20 Model CLP, and seven Model SLS for a fleet total of 47. This is in contrast to a fleet of 62 aircraft with the higher minimum frequency applied to each route.

U.S. international fleet mix: The 20-percent relaxation of minimum frequencies in this market results in a fleet size reduction from 19 aircraft to

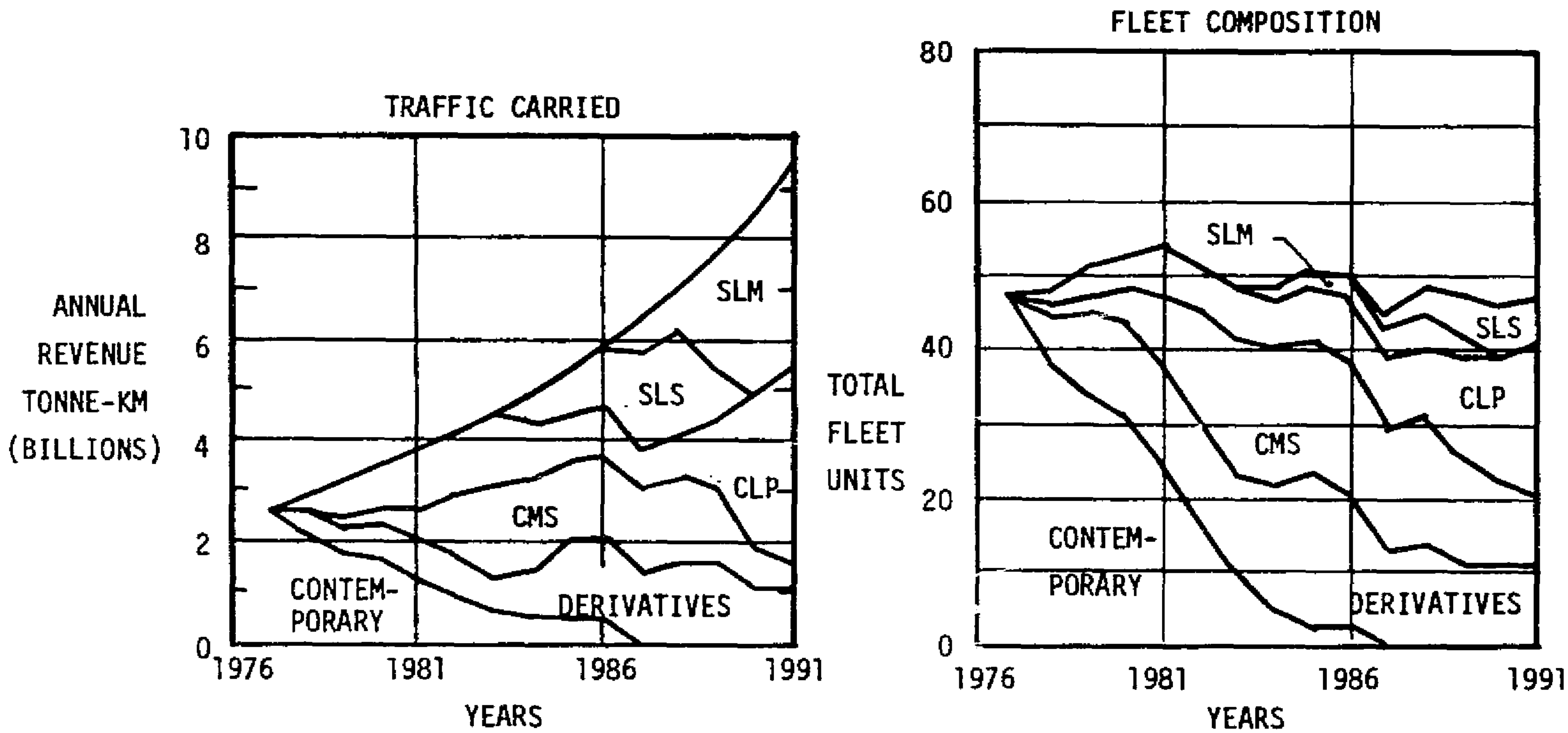

Figure 11-15. Effect of a 20-Percent Reduction in Minimum Frequency Limits, U.S. Domestic Air Cargo Market

16 in the year 1991. This mix consists of two Model DC-10-CD, one Model CMS, three Model CLP, seven Model SLS, and three Model SLM. Traffic and fleet units are shown in Figure 11-16.

Foreign fleet mix: The results of reduced minimum frequencies in the foreign air cargo market are shown in Figure 11-17. As in the previous markets, the mix shifts toward increased numbers of large aircraft with a total reduction in fleet size. The fleet in 1991 is decreased from 186 to 154 units. Again, the derivatives are reduced in number with the Models CLP and SLS being required in larger numbers. This is compared with the previous fleet evaluations with a higher level of flight frequency requirements.

Demand Evaluation

In summarizing the operational simulation exercises and fleet evaluations, it is appropriate briefly to review a few pertinent items. This will put in perspective the conclusions to be drawn concerning future requirements for cargo aircraft.

A review of the market and network characteristics includes the traffic projections to 1990, structure and constraints of the networks, and comments on the considered aircraft. Subsequent discussion considers the operational fleets as mixtures of aircraft appropriate for each of the markets. The demand is expressed as required numbers of aircraft in each econometric fleet mix. These numbers are relative only and, as such, merely indicate the potential of the respective aircraft to fulfill the air transport need.

Market and network characteristics. - The market forecast was extended to 1991 and included only estimated demand for all-cargo scheduled service. The network was held constant over the entire simulation period.

Cargo traffic projections: A simplifying assumption of 57 percent of the Baseline Scenario 2 forecast (Section 2) served to eliminate cargo flights scheduled on passenger aircraft, either belly-pit cargo or as a convertible freighter. This fraction of total cargo demand was preserved in all three

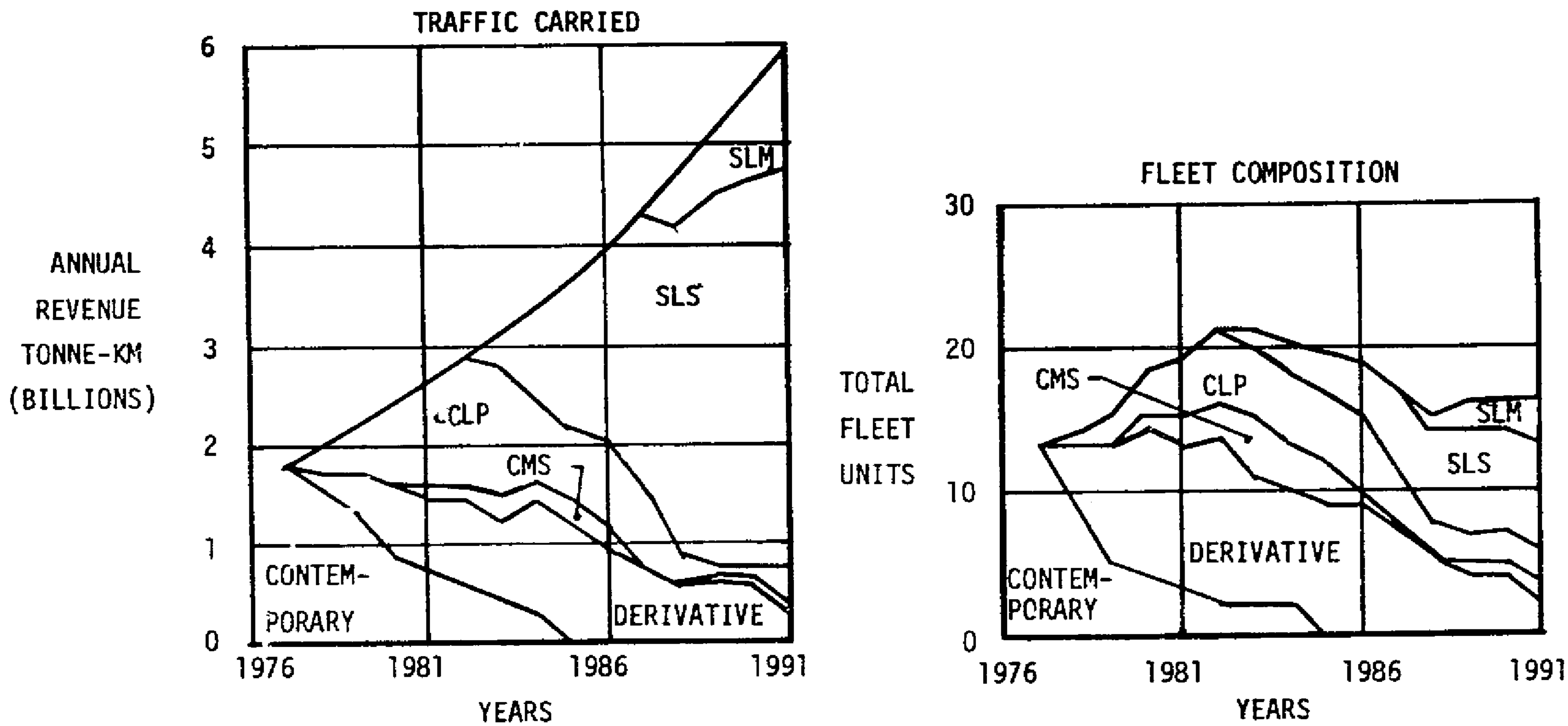

Figure 11-16. Effect of a 20-Percent Reduction in Minimum Frequency Limits, U.S. International Air Cargo Market

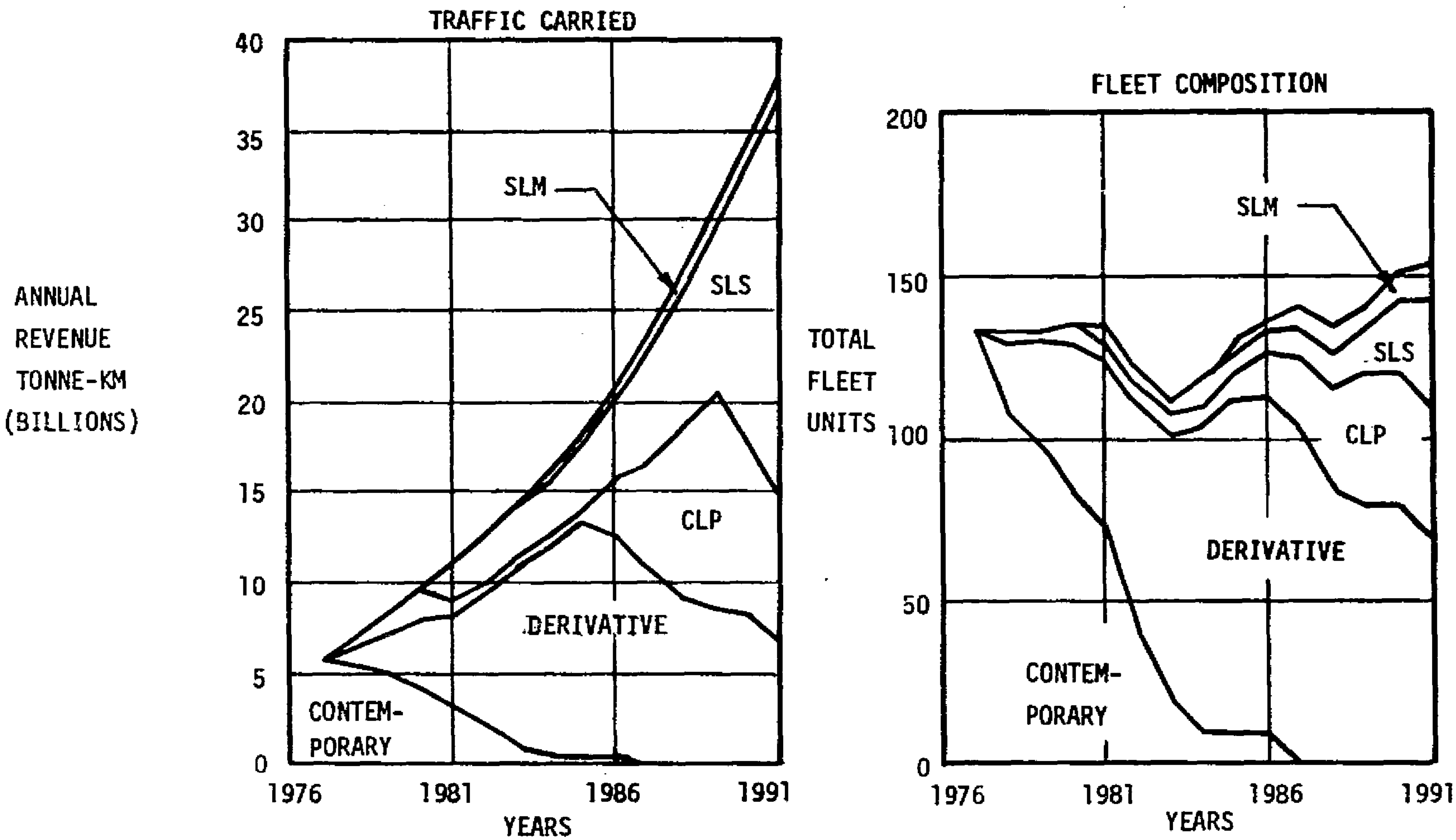

Figure 11-17. Effect of 20-Percent Reduction in Minimum Frequency Limits, Foreign Air Cargo Markets

markets for the entire 15-year simulation period. It was also assumed that all elements in the traffic model grew at the estimated rate shown in Section 2.

Structure and constraints of network: The August 1977 OAG flight schedule data were accumulated by frequencies for city-pairs, scheduled capacity by aircraft type, and distances between city-pairs. These data were aggregated into range class elements. Each range class element consists of a minimum number of flights and a total traffic requirement of tonne-kilometers as established by the growth forecast.

Since the number of range-class elements is held constant, the network structure is unchanged during the forecasted operational simulation from 1977 through 1991. In the real world, it might be expected that new routes would be added as the total market expands. These routes probably would have relatively low levels of traffic with corresponding need for either small cargo aircraft or low frequency of service.

The effect of a constant number of elements and a uniform growth rate among all elements is to reduce the need for the smaller aircraft in the fleet mix. Thus the fleet mix may have a slight bias towards larger aircraft. A more detailed solution to the fleet mix analysis would vary the network structure and the distribution of the cargo market growth. This approach would more accurately consider the case for the small aircraft.

The requirement to maintain flight frequencies at a level equal to or greater than the 1977 schedule assures the same or better level of service through the entire simulation period. The effect of this is to retain the small types of aircraft in the fleet mix. Without this constraint, the larger aircraft with lower load-unit costs (dollars per tonne-kilometer) would be selected on a least-cost basis.

<u>Candidate aircraft.</u> - Various fleet econometric mixes were generated in each of the three markets. The selected aircraft were drawn from an inventory of types classed as contemporary, derivative, and advanced concepts aircraft. Each of these types of aircraft was described in terms of range-payload

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performance, block time and block fuel functions, trip cost functions, and a 1977 purchase price or equivalent investment value. A single set of descriptors is used for each contemporary configuration. In the real world of airline operations, each cargo carrier has its own configurations and set of performance descriptions. These descriptors result from physical, operational, and accounting functions that are unique with respect to each of the operators.

Derivative cargo aircraft: The list of derivative aircraft presented in Table 11-2 is representative of types of aircraft currently planned or in development. The list covers the same spectrum of aircraft size classes as in the contemporary list of Table 11-1. Any number of other derivative aircraft could be included; however, they would fit into these general spectra shown in Table 11-2.

Advanced concepts aircraft: All of these aircraft are categorized as long-range, medium- to heavy-lift aircraft. Details of these aircraft were listed in Table 11-3. Of those selected in the operational simulation, the Model Civil Military, Small (CMS) is smaller than the DC-10 cargo aircraft. The Civil, Low Pressure aircraft (CLP) is larger than the B747, with a wingspan of about 21 meters (70 feet) greater. This greater span will require changes in airport layout to provide proper wingtip clearances. Other dimensions of the CLP are compatible with present airport facilities.

Operational simulation fleet results. - The nine fleet mixes in the three markets were all tabulated in Figures 11-6 through 11-14. For convenience in generating fleet mixes, both the derivative and advanced aircraft were introduced in the second year of the evaluation period. Although the resulting econometric fleet numbers are not real, two characteristic market reactions are noted.

The introduction of derivative aircraft results in replacement of contemporary models. The replacement is quite rapid, with the smaller aircraft DC-9, B737, B722, phasing out most quickly. The DC-10-CD emerges dominant. In the U.S. domestic and international markets, the Model DC-10-CD contributes the most traffic carried, as well as being the most numerous in the fleet. This is

demonstrated in Figures 11-9 and 11-10. In the foreign market, the Model DC-10-CD has an even greater role, as illustrated in Figure 11-11.

In the real world, the DC-10-CD model could not be introduced until about 1980. The Models DC-X-A and DC-X-B would not be introduced until the -1980s, probably 1984 or 1985. Thus, the displacement of contemporary aircraft would be shifted further into the future. Following intorduction, the trends would occur as demonstrated.

When the advanced concept aircraft are introduced in addition to the derivatives, the econometric fleet mix becomes dominated by the new conceptual configurations. The U.S. domestic market results are shown in Figure 11-12. The contemporary aircraft continue to be required in the fleet until about 1989 or 1990. However, the decrease in the total number of aircraft is more rapid than it was when only the derivative aircraft were added.

Again it should be noted that the numbers of aircraft are academic only. As an example, the advanced concept aircraft would be introduced no earlier than 1990 and probably not until 1995. By 1990 the market will have grown sufficiently to begin accommodating the larger size aircraft. The rapid penetration by these aircraft shown in Figure 11-12 illustrates their potential viability in serving this future demand. Econometric fleet mixes for the U.S. international market illustrate similar potentials for the respective aircraft; however, the smaller market would require less of each size aircraft.

In the foreign air cargo market, the derivative aircraft maintain a relatively high potential in competition with the advanced conceptual aircraft. This is illustrated in Figure 11-14. Of the derivatives, the Model DC-10-CD best satisfies the combination of range, flight frequencies required, and demand for cargo transport. Even though the advanced aircraft might be more efficient on pure cost per unit of cargo hauled, the demands of the market require smaller aircraft on the many city-pairs to be served.

Interpretation of fleet mixes and numbers: The objective of this operational simulation was to identify the general performance potential of the candidate aircraft which best satisfied the estimated cargo market demand.

In the simulation program, those aircraft were selected which met this objective with the least cost in each range-class element.

The assignment of the Model DC-10-CD to so much of each of the three markets indicates a majority of distances flown are accomplished at the desired payload fraction within the design range of the aircraft. The elimination of contemporary aircraft after 1986 is attributable to superior cost characteristics of the derivative aircraft at the assigned range and payload combinations. The assignment of seven Model DC-9-CD aircraft indicates only a few range elements with combinations of distance, payload, and required frequency of service that preclude a larger aircraft. There are routes at medium to long ranges for which the Models DC-X-A and DC-X-B are the least-cost aircraft meeting the payload factor and frequency criteria.

Air cargo fleet economics. - It is a general tenet of airline operations to be profitable. In generating profits from operations, the important factors are cash flow, net operating income and total investment in operating equipment. The last is defined in the simulation as the accumulated value of aircraft in the first year plus all others added through the 15-year period. Net operating income and the uniform annual cash flow are the results of the following steps in the simulation process.

- Cargo revenue is generated by the rate charged and the revenue tonne-kilometers generated in each year.
- Direct operating cost is generated for each aircraft for the total number of trips flown in each market element.
- Indirect operating cost is a constant fraction of revenue.
- Operating income is net of revenue less direct and indirect cost.
- Depreciation is excluded from direct operating cost but included in computing cash flow. Insurance also is included with depreciation.
- Total cash flow is the net of total revenue plus the salvage value of the depreciated fleet at the end of the 15-year

period less direct and indirect operating cost, depreciation and insurance charges on the aircraft, and corporate income taxes.

- Uniform annual cash flow is the total cash flow discounted back to 1977 and divided by 15.
- The return on investment index is equivalent to the interest rate at which the present value of investment in equipment is repaid by the net receipts generated by the operations of the equipment.

A plot of data such as that shown in Figure 11-18 provides guidelines in evaluating a decision to expand the existing fleet of aircraft or replace existing aircraft types with more efficient derivatives or completely new development aircraft. To an individual airline, a plot such as this will indicate whether expanding investment will increase both the cash flow and the return on investment. Expansion of both is an ideal choice for the operation. To an aircraft manufacturer, the total market potential must be evaluated as to whether the demand for aircraft can be satisfied by a derivative with a moderate development cost or by a new configuration with a massive development cost. In either event, the total number of aircraft to be produced is a dominant factor in establishing the appropriate price and hence the operating economies.

Interpretation of fleet economics. - Resulting values derived for the economics parameters are presented in Figure 11-18 for each fleet mix in each of the markets as shown in the legend. These data show a simplified view of the economic picture associated with the specific fleet mixes of considered aircraft. The size of each of the three markets is clearly shown by the fleet investment and annual cash flow levels for each. Differences in the assumptions for tariff levels and indirect operating costs are shown by the different values for the return on investment index. For example, the foreign cargo tariff was about 60 percent higher than the U.S. international market level and about 20 percent higher than the U.S. domestic cargo tariff. The level used for indirect operating cost in the foreign market was about 17 percent lower than in the U.S. markets. The combination of higher revenues

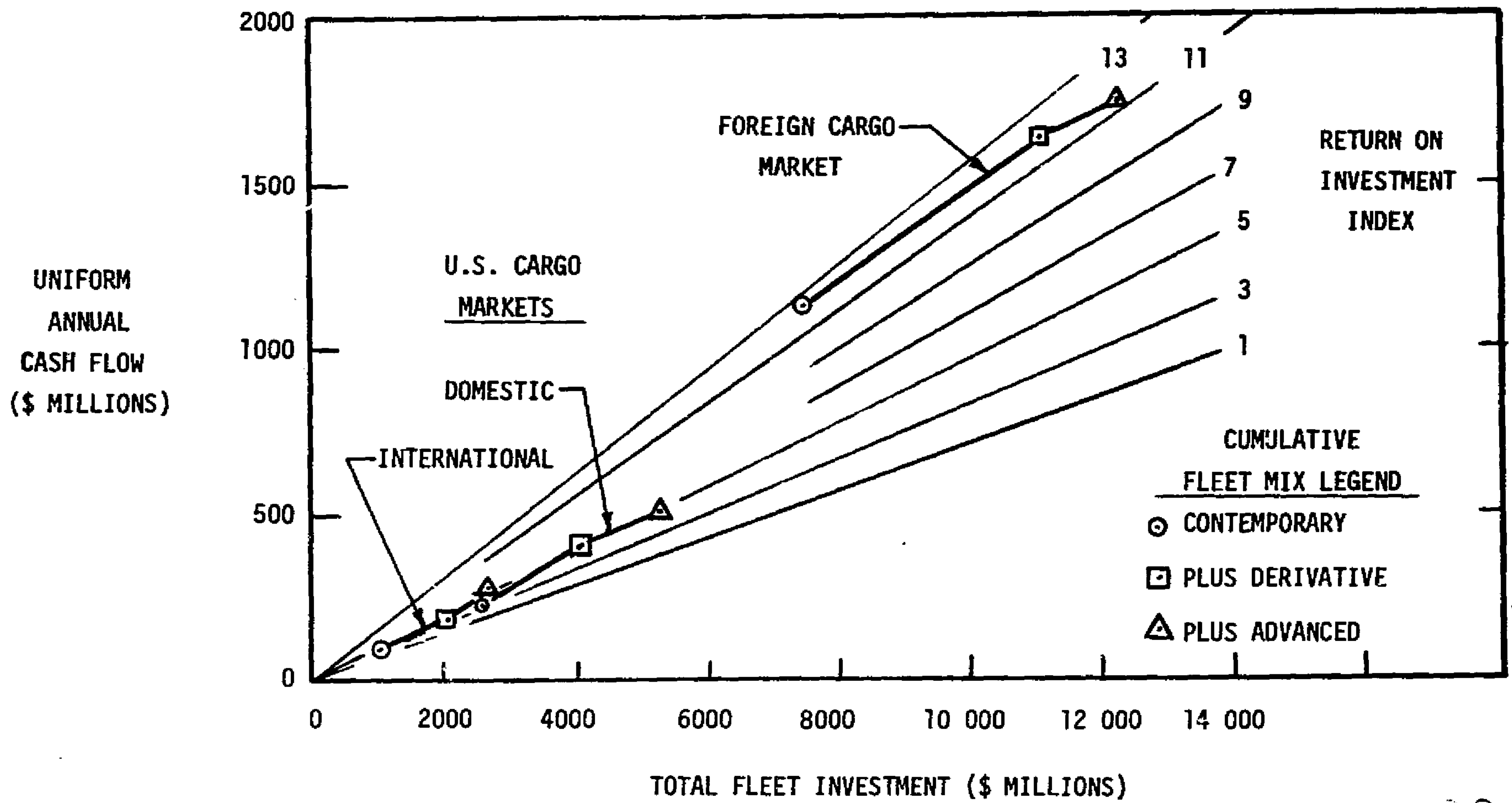

Figure 11-18. Air Cargo Fleet Economics

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and relatively lower costs combines to yield higher levels of income and a return on investment index in the foreign market.

In each of the three markets studied, addition of derivative and advanced aircraft increased both total fleet investment and annual cash flow. In the U.S. markets, the derivative aircraft increase both the annual cash flow and the return on investment index. The advanced concept aircraft enjoy a slight increase in the rate of return index in the international market, from 4.96 to 5.03, but suffer a slight reduction in the domestic market, from 5.35 to 5.17.

Of the three fleet mixes in the foreign air cargo market, the contemporary fleet generates the highest return index. This is 12.52 compared to the results of 12.04 with derivative configurations and 11.46 with derivative plus advanced concepts. The variations in economic results among the three markets illustrate the subtleties in generating a fleet mix with demand, cost, payload fraction, and minimum levels of service to be provided.

Potential of considered concepts. - The combined econometric and performance results indicate that within the considered time period there is a good potential for a derivative aircraft with the performance characteristics of the Model DC-10-CD. A lesser potential is indicated for a derivative aircraft having characteristics similar to the twin-engined DC-X-A or DC-X-B. It would be most probable that only one configuration would be developed in this class. However, the addition of more routes with reduced stage lengths, less than 3000 kilometers, would increase the potential for this regional size aircraft.

The current deregulation of cargo air carrier operations is anticipated to generate additonal service to new cities at reduced stage lengths. As mentioned in prior text, the simulation model as used in this analysis does not provide for such new routes at the lower, less-dense traffic end of the market. Thus, the demand for the smaller aircraft was not adequately quantified.

A review of the relative performance and economic potential of the considered aircraft in each of the fleet mixes provides a few general comments.

- If only contemporary aircraft were to be used, an aircraft of the B747 class would carry the bulk of the traffic with a continuing demand for the DC-8, B707 narrow-body type of aircraft. This latter is most prominent in the foreign market.
- The addition of derivative aircraft forces a rapid replacement of contemporary types with the dominant configuration equivalent to a three-engined DC-10 type derivative. Of lesser, but significant importance would be a shorter-range twin-engined, wide-body configuration like the Model DC-X-A or DC-X-B.
- Very little demand exists for a derivative small, short-range, narrow-bodied cargo aircraft of the DC-9-CD type.
- Within the ground rules and constraints of the operational simulation, the introduction of derivative aircraft generates a larger total fleet than would be generated by continued use of contemporary aircraft only. This might indicate that contemporary aircraft are not as well matched to the market as the derivatives would be. This is especially noted in the U.S. markets where the derivative cargo fleet is almost double the contemporary fleet. In the foreign market, the increase in fleet size is about 10 percent greater.
- Of the advanced conceptual aircraft generally considered as candidates for a joint civil-military concept, only one appears in the resulting fleet, Model CMS. It would not compete with derivative aircraft until 1991 and even then its potential to capture a portion is extremely low. It is evident that the cost and performance penalties associated with the military requirements incorporated in the Model CMS would make this approach noncompetitive in the civil aircraft market.
- The Model CLP, designed solely as a commercial transport, does appear in the three fleets, displacing some derivatives in the U.S. markets. In the foreign market, there is a lesser demand for the CLP than for derivatives.

- The spanloader concepts, SLS and SLM, appear only when the market is large enough to require those sizes at the required flight frequencies. This would not occur until well after 1990 with the predicted and continued expansion of the cargo market.

Application of Large Aircraft in the Hub-Concept

In Section 4, the hub-concept is considered for its ability to reduce or eliminate the back-haul problem prevalent on many international routes. Since results are favorable, this section will consider the compatibility of large aircraft to the interhub cargo flow between the U.S. and the Japan, South America, and French hub-spoke markets. These markets along with the forecast 1990 annual cargo flows developed in Section 4 are shown in Table 11-7.

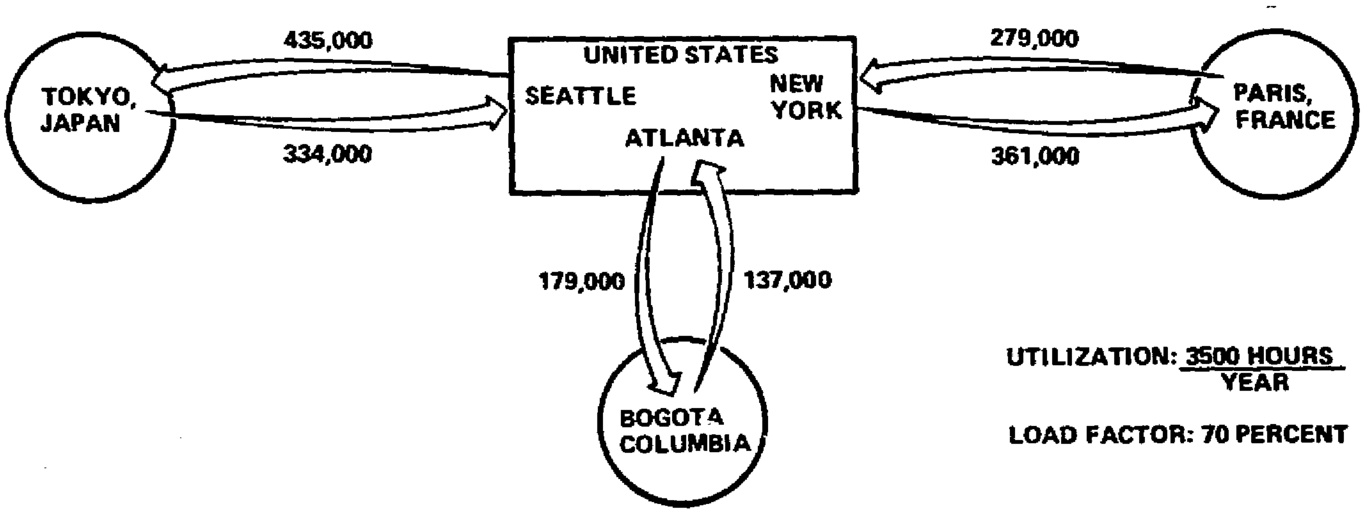
Large dedicated aircraft. - The models of large dedicated cargo aircraft considered in this analysis are listed in the left column of Table 11-7 and are the aircraft evaluated in the network analysis of the preceding subsection. This table also shows the operational characteristics, block time, and payload for each aircraft model for each of the specific hub-spoke markets identified by the hub city. Aircraft applications are based upon 3500 hours per year utilization and an aircraft load factor of 70 percent. Due to the long haul operations between hubs, it is assumed that aircraft utilization could be maximized realizing a level exceeding the 2800- to 3000-hour average prevalent in today's commercial operations.

Based upon the respective block times and payloads listed in Table 11-7, the number of each model aircraft required to serve the forecast markets and the corresponding number of flights per week were simply computed. No allowances were made for the variations in winds with direction. Note that due to the New York-Paris stage lengths the payload for the B747-300F (B747-Derivative) is reduced and that on the Seattle-Tokyo run the payloads of all models are reduced. The resulting levels presented in reference table are based upon a full aircraft or flight for any fraction greater than one. As an example, if a given market required 1.1 aircraft it is assumed that two aircraft are needed.

Table 11-7

HUB-SPOKE AIRCRAFT UTILIZATION

(1990 Tonnes)



AIRCRAFT MODEL	ATLANTA – BOGOTA				NEW YORK – PARIS				SEATTLE TOKYO				TOTAL NUMBER AIRCRAFT
	BLOCK TIME (HR)	PAY-LOAD (Kg) x 10^3	NO. OF AIRCRAFT	NO. FLT PER WEEK	BLOCK TIME (HR)	PAY-LOAD (Kg) x 10^3	NO. OF AIRCRAFT	NO. FLT PER WEEK	BLOCK TIME (HR)	PAY-LOAD (Kg) x 10^3	NO. OF AIRCRAFT	NO. FLT PER WEEK	
B747-300F	4.4	111	6	31	7.7	99	23	71	10.0	76	48	178	77
CIVIL/MILITARY													
Small CMS	4.5	59	12	59	8.0	59	40	118	10.5	52	72	162	124
Medium CMM	4.5	118	6	30	8.0	118	20	59	10.5	96	39	88	65
DEDICATED CIVIL Low Pressure CLP	5.1	154	5	23	9.2	154	18	45	12.1	132	33	64	56
SPAN LOADER													
Small SLS	4.6	317	3	11	8.2	317	8	22	10.7	272	14	31	25
Medium SLM	4.4	475	2	8	8.2	475	6	15	10.7	427	9	20	17

Examining these data, it is seen that the largest number of flights per week per aircraft occurs with the smaller payload aircraft in the Atlanta-Bogota market, a little over five flights per week. On the other hand, the larger aircraft operating over the longest stage length, Seattle-Tokyo, need only make two flights per week per aircraft.

A summary of the number of aircraft required to service the through markets is presented in the right-hand column of Table 11-7. The number required is essentially a function of payload; the small variations in block time for the respective models is almost negligible. The largest number of aircraft therefore corresponding to the smallest payload, 59 000 kilograms for the Model CMS. The larger 475 000 kilogram spanloader, Model 1111, can serve the the three markets with only 17 aircraft.

The purpose of this analysis is not to define the future aircraft market but rather to illustrate the effect of aircraft size on potential aircraft production. The importance of the latter on the future of large dedicated cargo aircraft is discussed in Section 8. Considered here are three of the major future air cargo markets of the world from the standpoint of future growth and/or the level of flow. In spite of the relative market size, the total number of aircraft required is rather limited when viewed in the light of a minimum production run of 200 discussed in Section 8. However, the numbers shown in Table 11-7 do not represent the total requirement. As an example, as the market grows beyond 1990 due to the growing world economy and the additional market stimulated by the reduced tariffs associated with the more efficient aircraft (e.g., Models CLP, SLS, and SLM), additional aircraft will be required. There are also other markets in addition to the three considered, and there is the additional movement of mail and express that were excluded in this study.

The hub-spoke operation considered here, when implemented, will increase the demand for lesser-payload, regional-type aircraft with maximum range capabilities in the order of 4600 kilometers or less to handle the spoke stages. As the various hub-spoke networks materialize they will provide an opportunity to utilize the older aircraft being phased out of scheduled operations. While

less efficient than new regional aircraft, the fact that many will be fully depreciated will make their continued operation profitable during the implementation stage.

Institutional cross-impact. - As seen from the previous discussions, while the hub-spoke concept is favorable to large-size dedicated aircraft, this size advantage represents a primary handicap to their development when considered in the light of the foreseeable air cargo market. This matter of aircraft size also enters into institutional considerations (reference Section 5, Volume 1) that could represent the greatest barrier to large aircraft and/or the implementation of the hub-spoke concept. Bi- and multilateral agreements between nations often place restrictions on such operational factors as routes to be flown by the respective nation's aircraft, frequency of flights over a given stage, and gauge changes en route. It is evident that such agreements place restrictions on the hub-hub operations and the utilization of smaller more efficient aircraft to service the outlying (spoke) regions of the network. Such considerations are further complicated by the multiplicity of airlines serving a given market. As examples what would be the interairline arrangement for servicing the Atlanta-Bogota market using the dedicated civil aircraft, Model CLP, requiring five aircraft and 23 flights per week or the Seattle-Tokyo market requiring only nine Model SLM and 20 flights per week. This problem of institutional barriers represents a prime consideration in the future growth of the air cargo system and deserves a detailed investigation by multidiscipline task force. The solution to this problem rests not only in the technical and economic areas of the total environment but will be equally impacted by future political, legal, and social developments.

Section 12

SCENARIO OF EVENTS AFFECTING SYSTEM/MARKET GROWTH

The results of this study will be utilized to make decisions regarding an air cargo system that will be developed, implemented, and operated in a future total environment that will probably differ considerably from that in which we currently exist. The interim changes in the environment not only affect the course and characteristics of the system development but also of the market it is intended to serve. Credibility of the CLASS forecasts and system evaluations therefore require the definition of a scenario that provides an integrated picture of the future environment and the encompassed market growth and system development.

The usual approach to a study of this type is to initially define one or more scenarios that can provide the future framework within which to conduct desired investigations. For CLASS, the approach taken was considerably different due to the desire to develop a more thorough understanding of the interrelations between market and system development and to identify the system compatible with the associated affected market growth. Rather than develop a specific scenario, a list of the more probable changes that could occur between now and the year 2000 was first identified from published future analysis results. These changes were then utilized in the analysis as a basis for viewing the alternatives of choice associated with the relations between the sequential phases of the cargo market and system developments.

Completion of the respective investigations reported in the preceding sections provided the desired understanding of market/system relations. In addition, the collective effort provided a basic insight into the requirements for realizing the future potential cargo market growth as affected by the coordinated development of a complementary air transport system. This section provides a summary of the latter results in terms of a possible future scenario of market and system development framed within the more probable total environment. This qualitative type scenario identifies such items as, the events that may occur or should be prevented, actions that should be taken, and

requirements that should be met to achieve a desired future. For clarity the overall scenario is presented in the form of brief definition statements segregated under five basic headings, namely, World Environment To 2000, Transport Market, Surface Transport, All-Cargo Transport System, and Air Cargo System/Market Growth. In all cases, only the more influential factors and considerations are discussed. This arrangement was chosen as an aid to post-study consideration of alternatives.

World Environment To 2000

The future world environment will result from actions taken in the social, political, physical, technological, and economic arenas. During the course of the CLASS analysis, potential trends and changes forecast to occur in the respective arenas were examined for possible inter- and intra-arena effects. Where applicable these effects were then related to air cargo market and system developments. This analysis provided additional substantiation for a more probable scenario of future environmental development considered relatively influential to affecting a desired future course of air cargo growth. A majority of the developments identified below represent long-term trends, many of which are already in evidence. It is unlikely that any action on the part of the aircraft and/or air cargo industry could change the course of these trends once they are established in the world environment. The primary area, either market or system, that can be impacted by each of the potential developments is identified as follows:

M - for the market area encompassing the location, size, and commodities

S - for the transport system encompassing the aircraft, network, and operations

Social Environment. -

Impact Area	Potential Social Developments
M	Early 1980s will see developed countries well into the "post-industrial" era. This era will be identified with the "post-extravagent" or "recycling society with increased emphasis on individuals and accompanying changing life styles.

M Continuing improvement in standard of living around the world. However, many developed and wealthy developing areas will become disenchanted with growth resulting in some previous growth forecasts failing to materialize. The rate of improvement in LDCs will be substantial in absolute terms although the gap with developed countries will continue to grow but at a decreasing rate.

M Social upheavals will continue in LDCs driven by "rising expectations" as influenced by growing intraworld communications at all levels of society. The growth rate of countries so affected will be reduced in relation to the scope and depth of this unrest.

M Urbanization will continue throughout the world but will be limited in some areas by the availability of water, food, and energy.

M There will be a gradual decline in the growth rate of world population; however, high rates will continue in some of the less developed regions of the world.

M S The percentage of the U.S. population residing in truly rural areas will decrease; however, there will be migration to nonmetropolitan communities including newly designed minicities. This movement will be spurred by communication, decentralization of industry, and energy availability. By 2000, 90 percent of U.S. population will be in urban areas with 45 to 55 percent of this number residing in the south and west.

M The U.S. will see a gradual reduction in the number of hours worked per year equating to a 35-hour work week by late 1990s. Over the same period, the number of professional and technical workers will increase with a greater portion having annual incomes of $25 000 (current) or more.

M By 1990, the U.S. will begin seeing a leveling off of the standard of living due to the combined effects of energy and social and environmental programs.

S The public view that major airport construction is a threat to general welfare will persist in the U.S. well into the 1980s.

Political Environment. -

Impact Area	Potential Political Developments
M S	Although there will be no major war, periods of political unrest will continue in many less-developed and underdeveloped

regions of the world. The uneasiness in the Mideast will continue well into the late 1980s and likely into the 1990s. In many cases, these conflicts will be felt in developed countries through the efforts of terrorist organizations who will take advantage of developments in transportation to achieve asylum and those in communications to make their cause known to the world.

M S There will be some grouping of LDCs by regions to promote military influence and into interregional resource-oriented cartels in an attempt to influence international relations and/or to minipulate trade. The supply and demand of mineral resources will exert an ever-increasing influence upon international relations. By 2000, there will be power shifts from the industrial to mineral-supplying countries.

M Ecophysical interdependencies will result in the grouping of nations with similar ideologies in areas of social, economic, and physical development. Such groupings will occur within and, in some cases, across political ideologies resulting in improved east-west trade relations. This increasing trade will be accompanied by some improvement in political relationships; however, the overall situation will remain difficult.

M S International political and/or monetary organizations will have a growing role in the discourse between nations with multinational corporations exerting a stabilizing influence upon international relations and trade.

S Political and economic forces encompassed within the world energy situation have the potential to stimulate international conflict and/or a world depression beginning in the late 1980s.

M S International oceanic resources rights will be arbitrated leading to sizable exploitation of the seas in the late 1990s.

M No major restrictive trading policies will be introduced, although there will be some protective measures periodically introduced to stimulate local manufacturing and/or reduce dependence.

M S The influence of the People's Republic of China in the Far East will increase considerably during next decade, while the political relations of the U.S. in Asia will weaken. Japan's influence will also continue to grow until it is playing a major role in world diplomacy by the late 1980s.

M The current armed conflicts in Africa will continue for some time with additional situations erupting in other regions of this continent as the relatively new countries develop their world orientations over the next decade. During this period of sociopolitical unrest, the USSR will proliferate the socialist form of government far beyond their current

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level of influence. This action will result in a degradation of the potential U.S. trade growth.

M S Many African countries will continue to be plagued by the problems of food distribution, shortages of energy, and a lack of variety in exportable commodities. Those countries rich in agriculture resources will exploit this industry in trade with Europe.

M Within the next decade Brazil will achieve power status equivalent to the current average of West European nations.

M South American countries will direct increasing efforts to industrial diversification and dispersal.

M U.S. will recognize the goal to achieve world leadership economically, technologically, and morally, while attempting to achieve self-sufficiency. This goal will result in strong involvement in technology assistance, foreign aid, and economic development programs for the less-developed countries.

S There will be increasing U.S. government control of technology development from the standpoints of product liability and preproduction impact analysis. At the same time, there will be increasing support of technology developments in the areas of energy, water, and mineral utilization including initial processing and recycling. Both these objectives will be handicapped by the lack of total planning by the Government.

S The coming decade will see increased public participation in U.S. government decisions through current and yet to be enacted legislation. As this trend continues, there will be a sizeable growth in the number of "special interest" groups attempting to sway legislation and decisions toward their particular interest.

Physical Environment. -

Impact Area	Potential Physical Developments
M S	The supply and distribution of food and natural resources will be a growing world problem with the industrial countries experiencing a growing dependence upon the mineral reserves in underdeveloped countries. Major concern will center upon the sources and security of energy and raw materials.
S	The demand for energy will increase at an estimated 4 percent per year out to 1990 with the EEC importing greater than 50 percent of its oil in 1985. Due to the lack of an adequate energy development plan, as opposed to energy conservation, the U.S. will not turn the corner on the energy problem until

the late 1990s. The overall situation will be worsened by the inability of non-OPEC oil suppliers to meet world needs before the mid-1980s. It is, therefore, a reasonable possibility that a worldwide oil shortage will begin in the early 1990s becoming critical around 2000 to 2010. Alternate energy sources will have little impact on demand until around the year 2000, when petroleum will be restricted to the transportation (excluding the automobile), fertilizer, and plastics industries.

M S Weather and social changes, combined with resulting impacts on food production and distribution, water availability, and energy demands, will be a growing concern during the coming decade. During the 1990s, the availability and distribution of water within various regions of the world will reach a level of importance comparable to that of energy. The U.S. will begin seeing the end to freely available water during the 1990s with further deterioration to a deficit level beginning at about the turn of the century.

M S The evolving world resources situation will result in modifications to industrial patterns at both the intra- and international levels. Hampered by natural and man-made barriers, the development of adequate surface transport infrastructures will lag behind these industrial changes. Driven by energy, labor, and capital considerations, U.S. manufacturing will continue to decentralize on a national and international basis. Within continental U.S., this movement, like population, will be to the South and West.

M S Within the U.S., megalopoli will develop around the following urban centers:

- Boston, Massachusetts, to Richmond, Virginia
- San Francisco, California, to San Diego, California
- Milwaukee, Wisconsin, to Chicago, Illinois, to Detroit, Michigan, to Cleveland, Ohio, to Buffalo, New York

Technological Environment. -

Impact Area	Potential Technological Developments, Excluding Transportation
M	Increasing levels of industrial technology through year 2000
M	Developing nations expected to spend $5.2 billion on communications prior to 1990. The world's energy problem will provide an additional impetus to developments in communications.
S	The lower cost plus improved information capacity of optical fibers will support the communications and the data management and handling revolutions.

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M	High growth in developments related to sea exploitation for food, minerals, and energy. Self contained, ocean-based, thermo-energy units will be producing electrical power and hydrogen fuel by 1990.
S	The nearly steady decline in the U.S. expenditures in R&D appears to have been halted. There will be a gradual growth in these expenditures approaching a level of 2.5 to 3 percent of the GNP over the next decade.
S	Increasing emphasis on the total energy concept, the type and quantity of energy expended to obtain an equivalent quantity of energy in the form of a convenience fuel.
M	Increasing world trade in technology especially for developing countries including the Peoples Republic of China.
M S	Rapid development of methods for the mass production of lightweight steel.
M S	Application of new technology within the U.S. will continue to be hampered by poorly informed special interest groups and by the decision process as affected by the Government's criteria/evaluation approach.

Economic Environment. -

Impact Area	Potential Economic Developments
M	World economic interdependence will become evident to even the most underdeveloped nations leading to a period where economic leverage becomes the weapon of international influence. As this interdependence grows, the world economy will continue to oscillate through the 1980s with at least one sizeable world recession prior to 1990. The combination of an unsteady economy and investments in developing countries will limit the real economic growth of developed nations.
M	Growth of the developing nations will not emulate the industrial nations but will take advantage of the current state of the art while leaning heavily upon external assistance through grants, developmental loans, and special trade concessions by developed nations. There will be a growing trend to develop necessary processing and manufacturing capabilities required to export products rather than raw resources. The development of such capabilities will tend to reduce trade barriers due to the associated need to compete in world markets. However, this trend will be limited by the increasing cost of fuel that will force non-oil-producing countries to impose barriers that will limit other imports.

M S There will be continued growth of multinational corporations particularly in developing economies with operations encompassing such activities as the contracting of government operations and the development of new cities and industries.

M S As industry and trade develop, the cost of labor increases with an accompanying trend to more capital-intensive operations. This trend results in the subsequent movement of the labor-intensive operations, such as assembly, to areas having cheaper labor. This behavior is illustrated by the movement of electronic assembly south from Japan. It is anticipated that China will grow as an assembly-type producer during the next decade.

M Relatively high growth rates will be achieved by underdeveloped and lesser-developed countries having raw material, stable governments, and favorable social conditions. Examples of such areas are Hong Kong, Phillipines, South Korea, Singapore, Malaysia, and Indonesia. Industrialization in these and other developing areas, such as South America, will portend strong markets for U.S. technology and hard goods.

M The price of raw materials will increase, driven by a combination of depletion, inflation, and other ecopolitical influences in the world markets. The total raw materials situation will result in changes in the role of business institutions; and new products and industries will develop in the areas of manufacturing, agriculture and ocean exploitation. In many areas of development, the growing cost of material, labor,and capital will offset the cost reductions that could be realized with the application of advanced technology.

M S The pattern of world interdependence, the dependence of developing nations on the rich nations,and concern over the debts of these developing nations, has led to an increasing concern about the future of the world economy. This growing situation will lead to a restructuring of the terms of trade over the next decade. This period will also see a substantial growth of the barter system, the trading of goods for other goods. These combined trends will lead to a proliferation of trading companies that will take on the responsibility of arranging trades and the transportation required for its implementation.

M Productivity of Western Europe will decrease to the U.S. level while the Japanese productivity remains higher. European countries will initiate policies directed to establishing stabilized economic growth; however, the long-term growth of OECD nations will not exceed 4 percent in real terms. Simultaneously, the U.S. economy will continue to grow but at a rate less than that which occurred during the 1945-1975 period. The real growth of the U.S. GNP will experience a long-term rate of less than 4 percent.

M S OPEC will remain a major force until the mid- to late 1980s since alternate energy sources will not have matured and the price of oil, less than or equal to \$25-\$30 per barrel, will not have been sufficient to make sophisticated recovery processes economically feasible. Through 1985-1990 the inflationary increase of 5 to 10 percent in fuel prices will not be sufficient to cause sudden economic dislocations of major economies. Beginning in the 1990s, as the market achieves balance between the production supply and the world's growing demand, there will be some additional increases in fuel prices above that due to inflation.

M S Continuing inflation throughout the world will affect the direction of trade and will force up the cost of capital with an accompanying increase in the cost of carrying inventory whether the goods be stockpiled in a warehouse or in transit.

M Although the growth of U.S. trade with China will be slow, it will provide a sizeable potential market for the higher-technology products. A similar situation will exist with other underdeveloped and less-developed countries where industrialization, however small, should portend strong markets for U.S. technology and hard goods. As these markets develop, there will be a proliferation of small to medium-sized U.S. businesses into the international market.

S A strong European aircraft industry will develop by 1985. This industry will encompass some combination of the Scandinavian countries, Italy, Australia, Japan, and Brazil, and will be a strong competitor for a growing aircraft market in the East.

M S Bolivia with its high ratio of resources to population has a very high potential for rapid and equitable economic growth. Since Bolivia is a landlocked country, as this growth takes place the accompanying increase in trade will provide an excellent opportunity for synergistic growth of air cargo and Bolivian industry.

M S Inflation in the U.S. will continue around 6 percent for some time. At the same time, the unit cost of labor in the transportation industry will experience annual increases of 4 to 6 percent with the cost by 1990 reaching a level about three times that of the 1977 cost. During the same period, the users cost of capital will approximately double with half that increase occurring prior to 1982. It is expected that the average effective corporate tax rate will decrease around 3.5 percent by the end of 1979. However, it appears that this decrease will be followed by a 1.5 to 2.0 percent increase in the 1981-1982 time period.

Transport Market

As discussed in Section 6 of Volume 1, the world trade revenue tonne-kilometers are expected to experience an annual growth of 4.5 percent. A prime issue of this study is to realistically determine the portion of this movement that can be expected to be performed by the air mode. In the past, a large number of these types of forecasts were overly optimistic, defining expected growths that were never realized. A primary source of this over-optimism was the failure to place affected market and system development events in the perspective of the effecting total environment. This section will, therefore, deal with those events associated with the consignor or consignee, demand, and commodity elements of the air cargo market.

A close examination of the total distribution costs associated with the world trade network shows that very few markets can be considered beyond further penetration by the air mode. This approach leads one to view a 400-percent growth factor (Reference 12-1) as a reasonable goal. However, as experience has shown, to achieve the encompassed additional 1.5-percent penetration above the current 0.5 percent is not an easy task. Any meaningful penetration of the transport market will require the mounting of a coordinated effort by the airline and aircraft manufacturers to assist the shipper to most effectively meet the demand for his product. It will be necessary to adjust operations and progressively tailor equipment to the growing market as affected by changes in the total environment. As the future unfolds, desirable and undesirable events will occur such as those defined below, that provide signposts for directed progress. The following events are the more important potential market-related happenings identified during the course of analysis. For convenience, they are segregated under the three basic elements of the market, namely, shippers and consignees, location and level of demand, and air cargo characteristics.

Shippers and consignees. -

- Shippers and consignees will grow more and more adamant in their desire for service. Service requirements will include the following:
  - Security - No damage or loss, traceability
  - Promptness - Ontime delivery with scheduling flexibility

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- Reliability - Door-to-door pickup and delivery when and where required
- Documentation - Simple and rapid with single-point contact
- Assistance - Knowledgeable transport personnel available for consultation, advice

- The increasing cost of capital and labor will place increasing emphasis on achieving the lowest cost for delivered goods. Transportation will be increasingly viewed as an element of the overall production chain involving the acquisition of material, processing, and distribution. Air cargo will be increasingly viewed in the total distribution perspective with credit for the flexibility this mode can provide in the uncertain economy.

- There will be an increasing number of small- and medium-sized companies entering the international market encouraged by the demand for high-technology goods and the national efforts to achieve balance of payments.

- As pointed out in Reference 12-2, there will be a continuing growth of multinationals on a worldwide basis. These organizations are involved with products characterized by rapid growth, high technology, and strong dependence on exports.

- The future will see a substantial proliferation in the application of the barter system (trade of goods for goods) throughout the world especially in trade with the underdeveloped and less-developed countries. These phenomena induce the expansion and/or creation of international trading companies. These organizations will handle all aspects of the selections, acquisition and disposal of commodities at both ends of the transaction and will arrange for required transportation. Operational practices, combined with the range of commodities handled, make the trading companies a likely candidate for air cargo penetration.

Location and level of demand. -

- As discussed in Section 6 of Volume 1, South America, Africa, Mid East, and Far East are the more promising international areas for potential air cargo expansion. Included in the Far East must be the Peoples Republic of China whose leaders have initiated a program of technology acquisition. Inherently, such an approach entails commodities compatible with air shipment.

- Domestically, the redistribution of industry and population to the South and Southwest will provide an opportunity for air cargo growth. At the same time, the states surrounding the Great Lakes will provide opportunities for further air penetration.

- The changing attitude and outlook of shippers and/or consignees discussed above can result in a gradual buildup in the use of air cargo on a regular shipment basis. However, as this occurs, the market becomes increasingly sensitive to air cargo rates.

- Express ocean shipments are expected to increase by an order of magnitude over the next two decades. A sizeable portion of this trade (Reference 12-3) are small shipments where the air rates are reasonably competitive as shown in Tables 4-17 through 4-28 of Volume 1. It should be noted that Reference 12-3 is only indicative of the potential since it lists only those shipments having a value greater than $250.

- The next decade will see a large growth in the flow of produce, fish, and meat from Africa to Europe in exchange for manufactured goods. It should be noted that this and other market growths will be hampered by the increasing dominance of Russia on the African continent.

- The future will see increasing application of air cargo in the trade between developed and developing countries. In some cases, countries are landlocked or have poor port facilities. In the latter case, pilferage and water damage are providing a strong incentive to ship by air. Increasing American investment in developing countries will assist the U.S. international airlines to penetrate these markets.

- The next decade will see a large expansion of extractive industries in developing areas and the succeeding decade will see the development of production capability utilizing the extracted material as a base. Such developments call for expensive, high-technology equipment and the meeting of completion dates, characteristics conducive to the application of air shipment.

- The future will see many opportunities for the synergistic combination of the airline and entrepeneur capabilities to establish new air cargo markets. Two current examples of this type of market development are the raising of eel for sales in the Orient and the shipping of garden plants from Dutch greenhouses to Florida.

- If the air cargo industry continues to develop in the future in a manner similar to that of the past, we can expect a domestic average annual growth rate of about 9.5 percent to occur within the constraints of the projected world environment to the year 1990. In a similar manner, the U.S. international revenue tonne-kilometers will experience an average annual growth of 8.3 percent, while the foreign carriers' growth will average around 14.3 percent a year. These values are discussed in detail in Section 2 of Volume 3.

- The north- and mid-Pacific region will experience a growth in the total air revenue tonne-kilometers (exports plus imports) of over 300 percent between now and 1990. Over the same period, air cargo movement between North and South America and across the North Atlantic is forecast to increase approximately 200 percent.

<u>Air cargo characteristics.</u> -

- No big surprises can be expected in the commodities shipped by air as discussed in Section 4, Volume 3. There will be some shifting of commodities into and out of the top 20 with an increasing share of machinery in the total volume. The manufactured goods portion of the world's freight movement is expected to increase at 1 to 2 percent per year.

- New products will enter the market, and many current ones will disappear, as they have in the past. However, the majority of these will not be apparent at the five-digit SITC code level. Perhaps the predominating trend will be toward miniaturization and compactness, which will tend toward increased density and weight.

- As discussed in Section 4, Volume 3, the present cost of airfreight makes commodities valued at less than 10 dollars per kilo unlikely candidates for air transport. In the future, reduced rates will lower this threshold, and continuing world inflation will increase the eligibility of many products.

- A major portion of air cargo's penetration of the surface transport market will occur in commodity classes No. 7 (machinery and transport equipment) and 8 (miscellaneous manufactured articles).

- Shipments to developing areas will grow most heavily in the areas of machinery and controls for extraction and processing of minerals, construction and maintenance equipment, agricultural machinery, food processing equipment, medical supplies and equipment, and communications equipment.

- There will be very little change in the warehouse density of future products shipped by air. The anticipated small increase in average densities will become neglible in the process of improving the loaded density of containers and aircraft.

- The increase in extractive operations in developing countries will provide a growing source of potential back-haul cargo. However, this will require a continuous monitoring of the mineral's economic status in the real-time world market and in the framework of existing total transportation system. Experience has shown that partially refined minerals, such as copper, experience market conditions that make air transport practical. It may be that some unique containers or other implementing features of the aircraft loading and unloading systems will have to be developed to reduce the overall costs of this type of back-haul operation.

Surface Transport System

Surface transport is important to this study because it represents competition to the air mode and most importantly competition in the future. It is essential, therefore, to clarify future developments in the respective surface modes and to understand the effect of such changes upon the mode's potential competitiveness. Only when one understands the competition can one effectively establish requirements for the air mode.

Due to the reactive approach to national development (as opposed to long-range, advanced planning) inherent in the U.S. legislature and society, it is quite probable that the present approach to the energy problem will continue. As a consequence, only relatively token programs directed to correcting the current energy-hungry surface transportation system can be expected to be initiated prior to 1985. However, as the year 1990 approaches, the criticality of the impending energy shortage will become obvious to even the most naive and will result in the initiation of meaningful surface transport programs during the last half of the 1980s. These programs will utilize the results of research and development conducted during the interim. However, due to the resources (time and money) required for their implementation, it is unlikely that the resulting new and/or modified surface systems can assist in relieving the national energy situation until the late 1990s.

Between now and 1985, effort will be directed to improving existing surface transport systems through the tailoring of currently advanced technology and the instigation of regulatory change. The qualitative impacts of many of the potential technological developments are outlined in Section 1 of Volume 3. As this effort proceeds, the resulting system changes will culminate in and be accompanied by mode-related events that will define growth in the context of the future environment. The more indicative of the potential future events, including those related to the infrastructure and effecting institutions, are listed below. As in the case of the future world environment to 2000, not all of these identified events will occur due to a variety of reasons. One of the more important of these is the legislature's preoccupation with the solution of current crises that were created through the lack of long-range planning in the past. This preoccupation will substantially

delay the integrated U.S. transportation plan that is a necessary prerequisite to assuring many of the desired events. The creation of this plan, as well as its subsequent implementation, will be greatly handicapped by special interest groups such as the respective industries themselves, environmentalists, and labor unions. For clarity, the identified events are segregated into five categories: general, motor, rail, and sea transport plus a fifth category identified as competitiveness.

General. -

- Transportation industry will be plagued by increasing operating costs due to labor, capital, material, taxes. This will result in increases in freight rates as a function of their respective importance in the considered mode's total operating cost.

- Energy considerations will play an ever-increasing role in program and operational decisions as affected by the increasing influence of government upon resource allocations. These influences will be felt in terms of the need to increase load factors and to eliminate ineffective frequencies and routes and will have the potential to affect changes in the market share by mode.

- There will be a moderate growth of public transport systems within major metropolitan areas. The energy and environmental situations will accelerate the application of these and existing systems to the transport of intra-metro freight during off-passenger peak periods.

- By 1990, a large portion of U.S. domestic movement will be taking place within the three developing megalopoli identified under the World Environment to 2000.

- The late 1980s will see increasing versatility in the application of pipelines for the transport of an increasing variety of freight (Reference 12-4). Of special interest will be the application of this mode to intra-urban freight transport.

- In consideration for energy efficiency there will be an increasing emphasis on reducing the number of separate power plants required to move domestic passengers and freight, i.e., truck-tractors to rail locomotive to central power plant.

- There will be gradual modification of government subsidies to surface transport in an effort to level the resulting intermodal advantages.

- Ecological considerations will result in increased emphasis being placed on land-use planning above and beyond that for pollution control. This planning will exert increasing influence on decisions related to airport expansion or development and upon the expansion of existing surface networks within and beyond urbanized areas.

- Energy cost and environmental requirements will have drastically affected the characteristics of automobiles by the late 1980s with an accompanying change in the American life style as regards inter-urban transportation. Among the impacts of this trend will be a substantial reduction in highway use and an attendant revamping of the tax structure that supports their maintenance.

- The next decade will see substantial improvement in the respective mode operators' attitude toward more cooperative intermodal approach. This trend will be stimulated by the workings of the surface transport market place as affected by a varying economy, a deteriorating energy situation, ecological considerations, and the related legislative (often poorly planned) actions. This trend will in turn result in the greater use of containers in domestic freight movement.

Motor transport. -

- The 1980s will see a substantial revision of the ICC regulations affecting entry, routing, and rate setting in the trucking industry. Changes will be similar to, but not as comprehensive as, the recent revisions to the air cargo regulations. Unlike the latter, any changes in the trucking industry will come slowly due to the opposition to change prevalent in the industry itself.

- Prior to 1985, increased weights, sizes and multiple tows will have been legislated into being within continental U.S. Comparable legislation will have established the federal structure necessary to evaluate highway maintenance costs attributable to trucking operations.

- Beginning in the mid-1980s, dedicated highway lanes will be established within the growing megalopoli and other large urban areas. Such action will be mandatory in those areas where shortsighted planning in the late 1970s failed to provide a more effective solution to the impending intra-urban movement problem.

- The more progressive trucking companies will apply automated data management to schedule cargo and dispatch trucks to be compatible with demand and highway traffic loading. This has the potential of reducing operating costs by increasing the productive utilization of the vehicle. Particular emphasis will be placed upon this approach by companies having routes that penetrate large urban areas.

- The future will see a proliferation of shipper associations (or coordinators) who coordinate traffic in both directions, thereby reducing the number of empty front or backhauls. Already operating on a national basis, this approach will be adopted to trucking operations within the developing megalopoli and large urban areas such as Los Angeles.

- The next decade will see improvements in truck engines, suspension and braking subsystems, and in vehicle design and construction (reference Section 1, Volume 3). Extensive developments such as dedicated highways with high-speed truck-trains are quite unlikely

to 1990. Past 1990, the energy situation will be a determining factor in selecting the method or methods by which the surface network can be expanded.

- Primary expansion of trucking operations will occur in intra-urban and short-haul (less than 500 km) movement.

Rail transport. -

- The early 1980s will see a largely revamped set of regulations controlling the rail transport industry. These revisions will progressively remove the existing barriers such as controls on rates, service (traffic) and diversification to rational and efficient operation.

- Institutional changes combined with the application of the total system approach to rail operations will result in an ever-increasing movement in the utilization of vehicles and infrastructure with an associated reduction in total operating cost. Many of these changes will be slow in coming due to labor's opposition to change.

- Until the late 1980s, the major thrust will be on improvements of the existing network. Later in this period, emphasis will be placed on improving the north-south elements of the system with some portions entailing new guideway construction. As this work proceeds, ever-increasing emphasis will be placed on electrification driven by the impending energy crises. Capital improvements, such as these and those to follow, will be impeded by the lack of financing. This situation will progressively ease beginning in the mid-1980s.

- Considerable progress will be made in improvements in rolling stock and road beds. The application of new materials in vehicle design and improved suspension systems will be utilized to achieve compatibility with new move efficient operating techniques and procedure. Initially, a major portion of these advancements will be achieved through the application of advanced European rail technology.

- The next decade will see the development of a new concept of guiderail construction. This concept will lend itself to nearly complete automation of initial construction and maintenance. The resulting guideway will be substantially less susceptible to weight and speed loadings, thereby providing meaningful reductions in maintenance. Construction techniques, such as laser drills and slump forming of cement, will be an integral part of this new concept.

- The future will see a proliferation of automated techniques throughout the rail infrastructure. Containerized cargo utilizing trucks and/or boxes will become a way of life and will, in some cases, be adopted to the movement of bulk cargo. This growth in container use will be accompanied by the development of compatible rail cars and loading equipment that can minimize the time consumed in loading and unloading. Dock-side gantries currently unload container ships at an average of 1.5 minutes per container.

- Application of automated data management will be applied to tracing and routing shipments and rolling stock; scheduling the size, number, speed, and routing of trains; and intranetwork transfers.

- The energy situation combined with improvements in rates and service will substantially increase the rail share of the domestic freight market. Reference 12-5 estimates this growth at 14 percent between now and 1995.

- The next decade will see a reinstatement of rail express utilizing passenger and fast freight trains. This service will differ considerably from the now-defunct past Railway Express service. This new service will be more of a less-than-carload-lot service with emphasis on smaller shipments of higher value goods where cross-country delivery in 3 to 4 days is acceptable. Eventually, automation will represent a key element in this service, although containerization will be employed immediately upon initiation of the service.

- Domestic high-speed rail freight systems will not be a threat to the air cargo industry prior to 1990; however, spurred on by the energy situation and institutional changes, the emergence of an effective interstate system will be eminent. This system will utilize the hub concept with local distribution (less than 500 km) by truck and some form of containerization. Lighter-weight, faster and smaller trains operating with automated marshalling yards and mechanized loading and unloading will be key elements in providing the required service.

- There will be a continuing proliferation of high-speed rail through Europe, England, and the oil-exporting countries. Many of these systems will have expanded to include high-speed freight by 1990.

- Several metropolitan areas will initiate construction of new and/or the expansion of intra- and/or interurban guideway mass transit systems. In the early 1980s, attention will be directed to utilizing these systems for freight movement during off-peak periods. Interest will be rekindled in the application of guideway systems to the problem of passenger and cargo interairport transfer and/or to relieve landside congestion.

Sea transport. -

- The use of container ships will increase in the future to the point where all freight except for bulk cargo will be containerized. Their size and efficiency will reduce frequencies and the number of ports served, increasing the need for air and surface feeder services.

- Although containerization has made the shipping industry capital intensive, the cost of labor runs a close second as a percent of the total operating cost (reference Section 6, Volume 3). Continuing increases in the cost of labor will be a determining factor in establishing profitable rates. It is debatable whether future improvements in efficiency can balance the labor increment.

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- There will be meaningful changes in world shipping conferences as they affect rate setting and freedom of entry. In any event, the U.S. industry will continue to be plagued by the heavily subsidized Soviet merchant fleet.

- During the considered time period, it is unlikely that any outstanding progress will be made in ship design or propulsion. Research and development will be directed to improving utilization and efficiency, fleet management, and cargo control.

- Relative to a modern container terminal there will be little improvement realized from additional mechanization and automation. However, there are gains to be made at many terminals where mechanization and automation is not utilizing the current level of technology. It is expected that the conversion to containerization will be essentially completed by 1990.

- The expected increase in ocean express will place emphasis on sea-train and sea-air operations. It will also increase the application of overland common point (OCP) operation. In this concept, all freight is unloaded into a common warehouse where it is stored on open pallets for later distribution by air or surface modes upon consignee demand.

- Sea containerization will not be completely effective until the handicap of intermediate jurisdictions (countries that must be transversed between origin and destination) to surface transport is eliminated. By 1990, there should be international agreement on standards for bonding, taxing, marking, documentation, safety, and customs handling of container shipments between origin and destination.

Competitiveness. - As pointed out in the discussions of the potential world environment and general surface transport events, the future is fraught with potential changes that will affect the respective transport modes in differing ways and varying degrees of severity. The result of these changes will be a realignment of the relative intermodal competitiveness, a consequence that must be considered in defining the future course of air cargo system development. A qualitative evaluation of the findings of Sections 3 and 6, Volume 3, lead to the definitions of the following events. Whether or not these events occur will provide an indicator of the relative penetration potential of the respective transport modes into the total transport market.

- Based upon comparable commodities and network characteristics, the relative importance of labor, capital and fuel costs to the respective modes were established. The following lists illustrate this importance by the order of listing with the cost element having the greatest impact potential listed first. In the case of international:

	Truck	Rail	Air	Ship
Domestic:	Labor Capital Fuel	Labor Capital Fuel	Labor Capital Fuel	
International:			Capital Fuel Labor	Capital Labor Fuel

The capital and fuel cost elements are of nearly equal importance.

- Compared on an intermodal basis the importance of the three considered cost elements to the overall transport picture was determined as follows. The mode most impacted by change in the respective cost elements is listed first with the remaining modes shown in descending order of the potential impact.

	Labor	Capital	Fuel
Domestic:	Truck Rail Air	Air Rail Truck	Air Rail Truck
International:	Ship Air	Ship Air	Air Ship

As noted by the brackets, the air and rail are rather close when it comes to the importance of labor and capital to their operating cost. As an example, in the case of current through-train operation, the labor increment becomes more important to rail than to air although the level of importance within each mode is below that for trucking.

- The relative future intermodal competitiveness between modes will be affected by the relative magnitude of the changes in the unit cost of labor, user's cost of capital, and fuel cost. Forecasts, discussed under World Environment to 2000, indicate that the cost of labor will triple while the cost of capital and fuel will double between now and 1990. As noted above, labor will be a predominating cost consideration for all modes with capital cost running a close second.

- As admitted by the trucking industry (Reference 12-6), this mode of transport is very labor intensive with a little hope of reducing cost through automation. There will be some reduction in labor cost through increases in the size and payloads of the transport vehicles.

- Both rail and air will improve their situation relative to labor. Although rail will see some increase in crews due to the instigation of smaller, faster trains, reductions due to institutional change

and developments (such as automated marshalling yards, reduced interline transfers, and automated data management) will more than compensate. Air will make its longest gain through containerization and improvements in terminal efficiencies. By 1990, both rail and air will see meaningful reductions in the labor increment of operating expenses.

- Due to the nature of the involved equipment, infrastructure, and capital availability, it is debatable whether the air mode or rail mode will be more susceptible to increases in the cost of capital. Although rail may be slightly less susceptible than air, the impact which it experiences will probably be greater than that experienced in the trucking industry.

- Based upon the increases in fuel cost due to inflation and availability, the trucking industry will be the least affected by raising prices. However, the trucking industry will experience additional incremental increases in fuel cost due to their ever-increasing proportional use of highways as automotive use declines. It is unlikely that any substantial relief will be realized through increased power plant efficiency and/or vehicle design.

- Internationally, the future will see the shipping industry most affected by rising labor and capital costs with the air mode substantially more adversely affected by increasing fuel costs.

- Based upon analysis of the current situation and through the application of future-oriented value judgments it is concluded that the air mode will substantially improve its competitive position relative to the surface modes. This will be achieved by taking advantage of the apparently undesirable economic trends in the areas of labor, capital, and energy resources.

- If the identified potential improvements in equipment and infrastructure are selectively implemented under the conditions of the anticipated increases in labor, capital, and fuel costs, the result will be a substantial increase in the rail share of the domestic freight market. A portion of this increase will be in transporting higher value commodities, a market segment previously lost by rail to motor transport.

- Considered in the framework of total production, distribution cost, the rising costs of labor, capital, and fuel have the added potential to increase the scope of air eligible commodities.

Air Cargo Transport System

Potential developments in aircraft, infrastructure, and operations will result in increased competitiveness of, and increased market penetration by, the air mode between now and 1990. The realized growth above that expected from a continuation of past performance will be relatively conservative until the late 1980s when the events discussed in this section will have transpired.

In the course of evaluating system developments, the following events were identified as being indicative of the necessary future relations to be established between these developments and system utilization and market growth. The key to increasing the future demand for airfreight service rests in the efficient use of resources, technology, and management to maximize productivity and customer service and to minimize operating expenses. This section deals with the technical, management, and productivity-related events, many of which are discussed in greater detail in other sections of this report. For clarity, they have been segregated under the general headings of airports, terminals and containers, aircraft, and operations. Events associated with rates and service are discussed in the section that follows, Air Cargo System/Market Growth.

These events will be realized only through responsible action by responsible groups. An attempt has been made to identify in a very gross sense where this action should occur. Complexes having the potential for affirmitive action toward the respective events are designated as follows:

G - Government, either U.S., Federal or local, or foreign

A - Aircraft industry

C - Airline industry

Airports. -

Affecting Complex	Potential Events
G, C	Growth in passenger and cargo traffic will result in competition for available ground space at high-density airports. Planning into the late 1980s will be directed to increasing passenger and cargo terminals and runway capacities at major hubs such as

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Atlanta, O'Hare, and Los Angeles. Beginning in the early 1990s, efforts will be redirected to new airports.

G By the late 1980s a major portion of the critical airport problems outside the U.S. will be solved. However, it is quite likely that the situation in many of the less-developed areas, such as the Aleutians, Rio-Sao Paulo, Pacific, Asia, and Africa, will be deteriorating relative to the growing demand.

G, C A growing number of major U.S. and foreign airports will have aircraft flow control restricting the number of arrivals and departures. These controls combined with landside saturation or restrictions could, in many cases, prevent any new airlines from initiating operations at such airports. For airlines already operating, potential relief may be achieved by moving all or part of their operation to other airports, or gradually converting to larger aircraft at reduced frequency as the demand increases.

G Air traffic control problems, and hence flow control, will be relieved with the installation of the FAA Upgraded Third Generation Air Traffic Control System with its capacity in the areas of vortex avoidance, aircraft metering and spacing, and discrete address beacon. Approaching the year 2000, the control system for all large and medium airports will be upgraded to a fourth generation system.

G, C Many major airports will have their capacities constrained by ground access congestion in the 1980s. This consideration will become a major factor in decisions relating to containerization and/or off-airport consolidation and unitization.

G, C, A Most major world airports will prohibit the operations of aircraft that do not meet the noise requirements specified by ICAO Annex 16 or the FAA Part 36. It is anticipated that even more stringent requirements will be enacted prior to 1990. This action will force the retirement or modification of a large number of existing narrow-body aircraft.

G, C There will be a proliferation of nighttime curfews at domestic airports and at many foreign airports. This could result in relocation of hub operations and/or the use of fewer but larger aircraft. Curfews will continue to handicap international operators.

G, C Airports dedicated to cargo operations will come into serious consideration in the late 1980s with implementation beginning in early 1990s. These will be combination of dedicated civilian and joint-use military airports. The number of the former will be limited since the revenue from a dedicated civil cargo airport will probably not be adequate to pay both operating expenses and debt retirement without substantial government subsidy.

G All-cargo airports will be located within 2 hours ground access time from select major production and consumption areas and from the areas' major passenger airport. High-speed off-highway transport will be provided to handle cargo transfers with adjacent passenger airports. Such arrangements are necessary to provide domestic overnight service.

A, C At many current airports the runway, taxiway, and apron/gate area dimensions cannot accommodate aircraft with wingspans or lengths significantly greater than the present B747 without encountering operational penalties. Changes to airports between now and 1990 will not be sufficient to substantially relieve these sizing restrictions.

<u>Terminals and containers.</u> -

C Present terminals will be adopted to 1990 flow levels through implementation of containers, automation, and revised intra-terminal procedures and layouts.

C Computerized documentation management and control will proliferate throughout the air cargo industry. As the market grows the scope of application will expand to include single billing; cargo routing, scheduling, and tracing that will encompass the minimization of interline transfers; flight scheduling; aircraft loading; storage scheduling; and customs documentation and clearance.

G, C Prior to 1990, there will be international accord on procedures and institutional change necessary for preclearance of customs. The airlines must champion this cause to assure early agreement and implementation.

C Terminal automation will include such items as improved ground handling equipment and storage volume utilization but will stop short of automated sorting. The latter will remain, for reasonable cost, incompatible with the continuing diversity in piece sizes and weights.

C By 1990, approximately 75 percent of air cargo will be in consignor-, forwarder-loaded containers. Of the remaining 25 percent, some 15 percent will still be accepted as bulk with the remaining 10 percent handled by the terminal accounted for by interline transfer.

G, C Off-airport airline cargo terminals will not be a major contributor to increasing flow-handling capability. At some major hubs, this approach will be forced by landside congestion and/or saturation of the airport cargo area.

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C The more efficient on-airport future terminals will provide direct onloading and offloading for the new generation aircraft designed for nose loading. There will be some cases where such system is adopted for forward side-door arrangements on derivative aircraft.

C, A Present unit-load device (ULD) cube utilization of 54 percent can be improved to realize achievable maximum cube utilizations of 85 to 90 percent. If realized, the resulting density may levy higher aircraft floor and fuselage shell structural load design requirements.

A, C Advances in materials and manufacturing technology will provide reductions in container tare weights and manufacturing costs of 30 percent. These advances, which apply to both air and surface containers, must be encouraged and supported by the air cargo industry.

A, C Technological progress substantiated by the growing use of containers will result in the development of unique, hybrid container designs that are compromises between security and weight. Included in these designs will be 3- and 6-meter containers for short-term warehousing and submodular ULDs compatible with direct sales floor display for consumer selection. From the standpoint of cargo handling costs, there will be modular designs directed to reducing interline transfer operations.

C Palletized loads built up by the airlines will still be in evidence in the 1980s. Shelf pallets and extra-height, high-cube pallets and containers will continue to be employed to develop the maximum payload cube capability of various cargo aircraft when operating over long stage lengths.

G, C By 1990, the shift from the 2.2-meter to the 2.4-meter container widths will be largely accomplished. The latter will represent a fundamental requirement for container channel sizing in future commercial cargo aircraft. Relative to existing air container designs, the AS-832 Type II will dominate over the Type I because of the corner fittings on the former. These fittings enable various ground handling equipment options, a characteristic that favors shippers and consignees.

C Between 50 and 75 percent of the forecast 1990 cargo market will be in 2.4- x 2.4- x 6-meter intermodal air containers. The remaining flow will be in belly pits, contoured pallets and containers, and 2.4- x 2.4- x 3-meter air containers. Based upon a warehouse density of 230.9 kilograms per cubic meter, cube utilization of 70 to 90 percent, and a provisioning factor of three (one container in the air plus two on the ground), this market demand will require approximately 20 000 of the 6-meter containers at a unit cost of 5000 1976 dollars.

G, C Although joint-tenancy cargo terminals may be getting underway on a modest scale by 1990, it is doubtful that the shift from the Air Force 463L system width of 2.7 meters down to 2.4 meters will be any more than in its infancy.

Aircraft. -

G, A, C Over the coming decade, the older, narrow-bodied aircraft will be retired from operations in the U.S. and the developed countries of the world. Those remaining will be modified to meet noise requirements or will be utilized for operation in regions where environmental controls are not so demanding.

A, C A regional-type aircraft will come into use around 1985. Derived from contemporary aircraft, these cargo configurations will utilize supercritical airfoils, composites in secondary structure, engines with lower fuel consumption, and higher bypass ratios for noise reduction and will realize reduced profile drag. The payload will be in the order of 40 to 55 000 kilograms at a design range of 2200 to 4600 kilometers.

A, C The air cargo market will have grown sufficiently to accommodate a large dedicated cargo aircraft in the post-1990 time period. This configuration will employ advanced technology in the form of a supercritical airfoil; composites for secondary and some primary structure; adhesive bonding; energy-efficient, quiet engines; active flight controls; and reduced profile drag. The payload will be equal to or greater than 154 000 kilograms at a range of 6700 kilometers.

G, A, C Between now and 1990, considerable effort will be directed to achieve a compromise between commercial and military requirements with the objective of defining a dedicated cargo aircraft configuration suitable for joint development.

A Future aircraft configurations will place emphasis on achieving compatibility with 2.4- x 2.4-meter containers and contemporary lower-deck containers and the implementation of a universal loading system incorporating automatic latching.

G, A Through the application of advanced technology, the large dedicated cargo aircraft can realize up to a 23 percent reduction in direct operating costs (DOC) compared to modern contemporary aircraft.

A The reduction in DOC due to reduced fuel consumption can be completely or partially offset by depreciation and insurance. There will be a growing emphasis on reducing the initial cost of new aircraft through design and increasing the production run through aircraft market expansion.

C The DOC cost element of airline operations will be reduced on the order of 7 percent by increasing the aircraft load factor from the current average of 60 to 65 percent to 70 percent.

G, C The size and number of new aircraft required will be strongly affected by institutional considerations such as the multilateral agreements affecting international operations.

<u>Operations.</u> -

C Out to 1990, improvements in infrastructure utilizing today's technology will be as important to cost reduction as the advanced all-cargo aircraft utilizing 1990 technology.

C The airlines can realize about a 23 to 29 percent reduction in indirect operating costs (IOC) through improved terminal efficiency achieved by increasing the number of customer-loaded containers, reducing import storage time and utilizing vertical storage. The first two needs can only be met through a concentrated effort by the airline sales force and management, respectively.

A, C As infrastructure improvements are made and the new dedicated cargo aircraft enter service, the importance of IOC will decrease and that of DOC will increase with respect to the total revenue. This will place even greater emphasis on advanced technology and the reduction of aircraft initial cost.

C The gradual implementation of improved terminal and aircraft productivity will lead to increased airline profits and return on investment in parallel with reduced tariffs. The latter could amount to as high as 24 percent by the year 2000.

C Deregulation will stimulate new entrants with innovative approaches that will lead to revisions not only of current operations but of shipper/airline relations. These consequences of deregulation will not become fully viable for 3 to 5 years.

C In spite of the innovative and competitive atmosphere, there will be a continued tendency toward price stability. As the market improves prior to 1985, the airlines will place emphasis on improving their financial situation through increased profit. With the potential cost reductions possible, this objective can be achieved without increasing tariffs.

G, A There will be increased emphasis on achieving Air Force/airline cooperation as illustrated by the Civil Reserve Air Fleet. Studies will be made to determine the economic and operational advantages of this approach from the viewpoints of the Air Force and the airlines, respectively. This effort will include the definition of military and commercial air eligibility characteristics as affected by a national emergency.

G, A New regulations will be developed concerning the handling and air transport of hazardous material.

G, A Hub-spoke network concept will see greater application in the future both domestically and internationally. Domestically, spokes having stage lengths less than 800 kilometers will probably be served by surface transport. Internationally, this concept will be employed to alleviate back-haul problems; however, its application will be handicapped for many years by institutional barriers. The government and airlines will mount a cooperative effort to have these barriers removed.

Air Cargo System/Market Growth

Future changes in rates and services are of prime concern when considering the growth of the air cargo market. Deregulation and many other events anticipated to occur in the total environment will affect the direction and magnitude of future rate changes and levels of services. These affecting events have been considered along with the analysis results of the previous sections to identify the future potential rate-setting procedures and service techniques defined in this section.

In all cases, the realization of the following events will require the considered efforts of the air cargo airlines. In addition, some will require the implementation of institutional changes that are presently at odds with change and/or innovation. This is especially true in the international scene. Such institutional changes will require the coordinated efforts of airlines and cognizant U.S. Government agencies. Many of the policies, agreements, and other regulatory instruments impacting the following events are discussed in Section 5 of Volume 1.

For clarity, the identified events have been categorized under the general headings of rate and service. Expected cost and service elasticities are included within the appropriate category.

Rate. -

- The future will see a proliferation of joint rates in combination with single billing and door-to-door rates available to the shipper/consignee.

- In many cases, such as wholesale markets and large shippers, rates will be negotiated and will include contract rates when shipments are made on a regular basis.

- Present rate setting procedures will be revised to take into account shipment size, volume, and density with the eventual elimination of specific commodity rates.

- Rate setting will be related to the service provided as indicated by the guaranteed delivery time, such as urgency and deferred service, and containerization such as size and whether or not it is shipper packed. Routine freight requiring guaranteed delivery date (not necessarily next day domestically or second day internationally) will be given increasing attention by airlines and forwarders.

- There will be a proliferation of charter and split-charter rates.

- Daylight rates will become more competitive in the future but will not attract the levels of cargo flow currently anticipated.

- The price elasticity of the air cargo market will increase such that a 10 percent reduction in tariffs will stimulate a 13 percent increase in demand. Since the air cargo industry is still early in its growth cycle, this elasticity will not develop spontaneously but will require determined prodding by the industry.

- As previously noted, the competitiveness of the trucking industry will decrease in the future due to their relative increase in operating expenses with comparable increased tariffs. A 10 percent increase in these tariffs will have the potential to stimulate an additional 1 percent in air cargo market growth.

<u>Service.</u> -

- Through the mid-1980s, the air cargo will concentrate their efforts on improving service. A reluctance to lower rates will make this an obvious course of action by which the airlines can increase their volume and revenue. These efforts will result in healthy customer relations.

- The scope and depth of bonded international forwarders' operations will increase in the future. These operations will include warehousing, consolidation, distribution, and break bulk handling. Communications networks will provide for real-time tracing of all shipments and the preclearance through import customs for all areas serviced.

- Airlines and their organizations, in cooperation with concerned governments, will work toward improved worldwide customs procedures incorporating data processing and management techniques and equipment. Simplified documentation and data processing will facilitate preclearance and guaranteed clearance and the reduction of import storage time from the current 3 day average to less than 1-1/2 days.

- There will be a concentrated effort to simplify and standardize commodity descriptions and coding systems on a worldwide basis and for all modes of transport.

- The airlines, in cooperation with forwarders, will accept the challenge of providing door-to-door service with single billing to cover all costs of the interim transportation.

- There will be a growth of companies oriented to supplying containers to the air transport industry similar to current practices in the sea transport industry. These container companies will acquire, lease, maintain and repair the 2.4- x 2.4-meter containers. Utilizing worldwide communication networks, in cooperation with the airlines, they will maintain real-time account of container location, maximize their utilization, and minimize the air movement of empty containers.

- In the event that container companies do not materialize, and/or for areas not serviced by container leasing companies, there will be a proliferation of associations with the objective of minimizing the movement of empty containers. Such operations are financed by relatively small charges when inbound and outbound container usage is matched.

- Governmental, social, and industrial institutions will remain a barrier to improved service in many domestic and international areas.

- Airlines will establish a "deferred service" category of service. This service will be provided at incentive rates with the objective of increasing selectivity and thereby container volume utilization.

- Airlines will develop the capability to perform the forwarders' job in new markets both domestically and internationally. Emphasis will be on providing overnight delivery domestically and second-day delivery internationally.

- There will be a proliferation of air-sea links. Where applicable, an overland common point will be established as the origin for intra-continental air distribution.

Section 13

FUTURE STUDY AND TECHNOLOGY REQUIREMENTS

This study has revealed no serious technical problems that could impede future air cargo market growth or the implementation of suitable aircraft to meet the accompanying air transportation demand. However, there were areas identified at both the system and technology levels where future study, research, and developmental efforts can appreciably enhance system and thereby market growth.

As the analysis progressed and the future efforts were reviewed in the total system context it became evident that many of the more important items fall under the cognizance of the engine and aircraft manufacturers, airline industry, and civil transport organizations such as IATA and ATA. The potential growth of the air cargo industry can be achieved through the coordinated efforts of these and other involved institutions working in parallel with the NASA to fulfill the requirements outlined below. In keeping with this thought, the general category of the institutions involved with the respective requirement are identified. Requirements are categorized under system studies and technology research and development.

System Studies

Design objectives for future cargo aircraft. - The objective of this NASA-contracted study will be to determine the design objectives for future dedicated cargo aircraft in terms of acquisition cost, direct operating cost, payload, range, and speed based upon their operation in a future, real-world OAG cargo network projected to the year 2020. The viability of the design objectives will be established on the basis of the resulting return on investment and profit provided to the airlines when operating in competition with contemporary aircraft.

Prior to the computerized analysis effort, a forecast future world network should be developed based upon a scenario of air cargo industry

progress to the year 2020. A parallel effort should forecast the future growth of airfreight in the U.S. domestic and international markets and in the foreign market considering the combined volumes of cargo, mail and express. Both these forecasts should utilize the CLASS results and must be accepted by all parties prior to their integration into the aircraft analysis.

Actual analysis can utilize the same computer program employed to develop the results given in Section 11. This effort, along with the data acquired during a previous NASA-directed study of future passenger aircraft, shows that the stated objective can be achieved with a relatively small resource investment. Results of this effort will provide a firm basis for identifying specific technologies and the associated level of their development required to design economically and operationally effective aircraft conducive to a financially healthy, service-oriented future airline industry.

Air cargo density. - The objective of this NASA-contracted study will be to analyze the effect of cargo density in aircraft structure as affected by containerization, universal loading and locking devices, pressurization, and fuselage shape.

This study must be based upon currently substantiated air cargo warehouse and loaded densities. While the Douglas CLASS surveys qualitatively substantiated the density data currently being used, it is generally recognized that an updated industry-wide survey of terminal throughputs is overdue. It is suggested that this effort be performed under the auspices of one or more of the airline transport organizations.

The terminal analysis of Section 3 and subsequent economic investigations identified the potential gains to be realized through improved container volume utilization and increased aircraft load factors. The prospects for achieving these improvements should be investigated with the airlines as a task of this proposed study. Results can then be consolidated into criteria to be utilized in the density/structure analysis.

This study is an essential element toward assurring an efficient dedicated cargo configuration at minimum initial cost.

<u>CRAF impact.</u> - The objective of this Air Force-contracted study will be to define the impact of the CRAF concept upon airline IOC, DOC, ROI, profit and tariffs, and upon future air cargo system and market growth.

While on the surface this approach to national emergency appears advantageous to both the military and commercial situation, there are non-economic factors which can present a handicap to commercial cargo growth. As an example, the shippers' fear of having their supply lines disrupted in the event of a national emergency and the airlines' fear of losing a critical portion of their equipment. Closely related to these concerns is the differences in the military and commercial definition of air eligible freight and, hence, the volume of emergency freight. A critical task of this study will establish clear definitions of each of these sets of air eligibility criteria. These results would provide a basis for reconciling the commercial and military desires and the definition of a clear set of guidelines to be applied to the shipment of air cargo during an emergency.

Although sponsored by the Air Force, this effort should be coordinated with and include the active participation of the airlines and their representing organizations.

<u>Dedicated cargo airports.</u> - The objective of this NASA- and/or FAA-contracted study will be to assess the political, physical, technical, social and economic potential of dedicated cargo airports as an alternative to current major passenger/cargo hubs considering both the new commercial and joint commercial/military tenancy.

This study should consider the impact on the local area and upon airline operation. In these respects, particular attention should be given to the cargo airports accessibility to the adjacent commercial, metropolitan area, including ground transport, and to the adjacent passenger/cargo hubs. The overall study should identify and outline solutions to the many problems associated with the development and subsequent operation of these cargo airports.

Results of the Douglas CLASS study identified the growth problem of current airports and terminals and pointed out their limitations in

accommodating future large, dedicated cargo aircraft. The operational and economic advantages of dedicated cargo airports to solve these problems should be investigatrd within the framework of the future air cargo market and airline network as affected by anticipated operational aircraft to the year 2020. This effort should be coordinated with and utilize the active participation of both the airlines and the Air Force.

Off airport consolidation. - The objective of this airline contracted study will be to assess the cost and service advantages and disadvantages of performing the consolidation and unitization functions at off airport facilities.

The Douglas CLASS results identified the current and future capacity and productivity characteristics of existing air cargo terminals and pointed out the potential for surface transport congestion at existing major airports. Each of these considerations points to off-airport containerization terminals as a potential solution although most airlines have the opinion that this approach will increase their operating cost. Considering the importance of terminals to cost and service and the timeliness of potential improvements thereto, this study represents a prime consideration for future growth. The potential of off-airport operations must be established to the satisfaction of the air cargo operators.

This study may be performed by the airlines themselves or by one or a combination of the civil transport organizations. Regardless of who performs the study, the effort must consider the views of the shippers, forwarders, and the planning organization having cognizance over the urban/commercial area surrounding the considered airports.

New international networks. - The objective of this civil transport organization and/or NASA-contracted study will be to investigate in depth the feasibility of new network concepts, such as the hub-spoke, as affected by institutional barriers and constraints.

This must be a multidiscipline effort that delves into the potential interrelations between new aircraft and network operational concepts and

the physical, social, economic, political, and legal aspects of applicable regional restrictions and/or multilateral agreements. The analysis must include the forecast of and agreement on the possible future restrictions and agreements to be considered. Emphasis should be placed on items affecting routing, frequency, aircraft size, and gauge change. Results of this study will provide a pertinent input into establishing the size and operational date of future large, dedicated cargo aircraft.

Demand elasticities. - The objective of this civil transport organization contracted study will be to perform a detailed analysis of demand elasticities due to rates, delivery times, frequencies, and cities served.

Data should be obtained from field surveys utilizing the "Cojoint" technique. This approach is directed to measuring the way air cargo users and potential users make choices between rate and service stimuli rather than relying on a self-reported preference. The survey approach is necessary due to the lack of historic data adequate for elasticity analysis. The small amount of data relating demand to cost and service is not adaptable to reporting the latter influence factors. In order to establish viable data, the survey sample must be relatively large, covering a broad range of shipper types who are oriented to and located within both domestic and foreign regions.

The Douglas CLASS study uncovered the fact that there is considerable misconception of the current and future levels of elasticity; although the apparent values are key considerations in planning future tariffs, service, and revenue. Analysis should be performed in close coordination with the airlines, which in combination with the determined elasticities, should provide a positive stimulus to airline advanced planning.

Mail and parcel post. - The objective of this NASA-contracted study will be to assess the impact of mail and parcel post on air cargo market growth and system development.

The CLASS study reported on herein excluded the consideration of mail and parcel post. However, during the course of the surveys and the analysis

of the current market, these two types of freight were identified as having the potential to provide a large addition to future airfreight movement. This study should determine the characteristics, volumes, and directions of current mail and express movement. Utilizing this as a base and considering future changes in the world's total environment, levels of movement anticipated to the year 2000 should be forecast. These data can then be applied to the CLASS results and their impact on aircraft, airports, terminals, and containerization evaluated.

Technology Research and Development

Continued NASA advanced technology. - Continued work on current advanced technology programs is essential for future derivative aircraft and mandatory for the large, dedicated cargo aircraft in the post-1990 time period. The more prominent of these programs include the following:

Energy-efficient engines	Laminar-flow control
Advanced turboprop engines	Quiet engines
Composite structure	Active flight controls
Adhesive bonding	

The importance of these and other programs is substantiated by the Douglas CLASS results that show the growing importance of aircraft direct operating costs as an element of the total revenue.

Cargo aircraft design criteria. - The objective of this NASA-contracted study is to analyze cargo aircraft structural design and to define design criteria and requirements as affected by civil and/or military application, exterior configuration, ULDs, cargo densities, fuselage pressurization, and load factors and is directed to the achievement of simple construction and reduced purchase price.

The Douglas CLASS survey results pointed out the desire of the cargo user for low cost and improved service and his lack of concern for the aircraft used. On the other hand, the analysis results pointed out the necessity for reducing the aircraft acquisition cost to minimum. These points combined with the substantiated need for future all-cargo aircraft underscores the need for technology assessment of innovative concepts that are compatible

with both the cost and service requirements. The range of cargo optimized concepts to be considered should include variations in wing and engine placement, turboprop and turbofan engines, fuselage interior considering ULD handling and restraint, and in the landing gear placement and configuration. Performance considerations should include the effect of speed, field length, and noise supression.

Results of this study should identify not only design criteria but also the type and level of technology compatible with the future market demand, minimum direct operating cost, and minimum production cost. This effort should be initiated on the basis of the results of the design objectives for the Future Cargo Aircraft System Study previously described.

Military and/or commercial cargo aircraft. - The objective of this NASA/Air Force-contracted study will be to evaluate the technical, operational, and economic advantages of separate and joint military and commercial cargo aircraft design, production, and operation as affected by ULDs, cargo size and density, and converting from dedicated commercial cargo to military cargo aircraft, military cargo to dedicated commercial cargo aircraft, passenger to cargo aircraft, and cargo to passenger aircraft.

Results of this work should orient the compromises in design to production and operational costs as well as to military and commercial operational requirements. With regard to the latter, the analysis should be coordinated with and solicit the participation of the airlines and civil transport organizations.

Constrained design alternatives. - The objective of this NASA-contracted study will be to define and assess design alternatives for large aircraft that are compatible with current airport and terminal constraints on span, length, height, and footprint pressure.

As the Douglas CLASS surveys pointed out, current major hubs place restrictions on aircraft size from the standpoint of clearance not only on the aprons but in passing on runways and/or taxiways. These limits combined

with pavement strength, constrain future aircraft size to about that of the current B747. While new airports are one solution to this problem, an alternative is to tailor the aircraft within the constraints. Analysis should therefore consider such items as the variations in fuselage length versus width, folding wing tips, and a landing gear capable of crabbed ground movement. These and other solutions should be evaluated for their impact on aircraft production cost, performance, direct operating costs, and productivity including turnaround time.

ULD handling and restraint. - The objective of this aircraft industry-sponsored effort will be to develop a universal fuselage loading and restraining system.

As pointed out by the Douglas CLASS analysis, the current aircraft loading system utilizes rollers, requires hand tie-down, and involves a weight penalty when accommodating the present surface 2.4- x 2.4-meter containers. This study should consider new and innovative approaches assessing the advantages and disadvantages with respect to turnaround time, variations in container size, fuselage structural design, aircraft weight, and production cost.

Before the actual analysis is initiated, the airline industry should be interrogated as to its requirements. Results of this survey should be analyzed and a set of standard, acceptable requirements defined. When approved, these requirements can be used as criteria in the development of designs suitable for incorporation in a variety of aircraft sizes.

ULD design and production. - The purpose of this manufacturer-sponsored study is to develop a family of ULD containers compatible with intermodal and interline operations that can be produced to minimum cost and with a minimum tare weight.

The Douglas CLASS results pointed out the feasibility of utilizing current technology to produce an intermodal, 2.4- x 2.4-meter container having a cost and tare weight 30 percent less than current containers. Further refinement may lead to even greater savings. In addition, this study should

consider the problem of interline transfer where, under present operations, the movement of partial container loads is both time and resource consuming. Efforts should be directed to the identification and investigation of innovative concepts that will alleviate this problem with minimum cost and weight penalties. Promising concepts should then be assessed for their potential contribution to airline direct and indirect operating costs.

Prior to and during this study, the airlines, forwarders, and shippers should be consulted for more detailed information as to their likes, dislikes, and requirements regarding containers. In addition, the technical effort should be coordinated with the related work on aircraft handling and restraints discussed above and investigations on fuselage versus container environmentalization.

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